NASA STEM
Flow Boiling in Micro-channel Experiment In Variable Gravity

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National Council of Space Grant Directors’
(Fall Meeting 2015)
Space Grant at New Mexico State University
Presentation outline

- What is the NASA STEM project?
- The experiment and its purpose
- Concerns
- The work and conclusions from the design phase
- Methods
- The team
What is the NASA STEM project?

The NASA STEM Project is a student ran program funded by NASA and the Space Grant Consortium at NMSU; to encourage retention and further involvement of our developing STEM students.

Participants get hands on experience in the development of cutting edge research, while developing the tools necessary to be successful in their field.
Purpose of the experiment

The understanding of flow boiling in varying gravity is crucial to space exploration. Due to a change in the effects of buoyancy on vapor, we experience limited surface area that is in contact with the heat transfer fluid in a hot channel. [1]

The effects of the channel size may impact the effectiveness of flow boiling and currently there is no literature on the effectiveness of flow boiling in a very small channel, (on the scale 5 mm). [2]

Our experiment will be within a channel that is 0.8 mm x 4 mm x 40 mm.

Component cooling in variable gravity environments
Next generation air craft
Future space missions
2-D diagram

Heater and micro-channel

Pump

Condenser and PCM
Concerns

Limit changing environmental effects on the system

**Structural**

- Increases and decreases in gravity
- Centrifugal forces
- Effects of change in pressure to the pump

**Thermal**

- Control external thermal effects to the system
- Ensure phase change occurs

**Electronic**

- Make sure our devices will work throughout the experiment
- Battery Power
Heat transfer analysis

Heat in (W) vs. Layers of insulation (n)
System analysis

The graphs illustrate the relationship between the size of the PCM cube and the weight of insulation as layers of insulation increase. The graphs show how the size of the PCM cube decreases with increasing layers of insulation, and how the weight of insulation increases.

For the 6 layers of insulation:

- **Skeletal Structure OD:** 188.00 mm (estimate)
- **Skeletal Structure Height:** 173.50 mm (estimate)

**10Watt Heater:**
- Total Trip Energy: 18636.68 joules
- PCM: 648.73 grams
- PCM Cubic Box side: 94.04 mm
- PCM + Insulation Weight: 1457.43 grams

**20Watt Heater:**
- Total Trip Energy: 30621.68 joules
- PCM: 558.89 grams
- PCM Cubic Box side: 89.48 mm
- PCM + Insulation Weight: 1367.59 grams

**30Watt Heater:**
- Total Trip Energy: 42606.67 joules
- PCM: 541.98 grams
- PCM Cubic Box side: 88.57 mm
- PCM + Insulation Weight: 1350.68 grams

**50Watt Heater:**
- Total Trip Energy: 66576.67 joules
- PCM: 549.01 grams
- PCM Cubic Box side: 88.95 mm
- PCM + Insulation Weight: 1357.71 grams
Structural FEA

* Exaggerated deformation in image, actual deformation is about the width of a human hair
Viable thermal fluids

* Pressure about 1 atm (pump)
* Boiling point above 27 C (PCM)

Isobaric Properties for Ethane, 2,2-dichloro-1,1,1-trifluoro- (R123)

<table>
<thead>
<tr>
<th>Temperature (C)</th>
<th>Pressure (MPa)</th>
<th>Density (kg/m3)</th>
<th>Volume (m3/kg)</th>
<th>Internal Energy (kJ/kg)</th>
<th>Enthalpy (kJ/kg)</th>
<th>Entropy (J/g*K)</th>
<th>Cv (J/g*K)</th>
<th>Cp (J/g*K)</th>
<th>Sound Spd. (m/s)</th>
<th>Joule-Thomson (K/MPa)</th>
<th>Viscosity (Pa*s)</th>
<th>Therm. Cond. (W/m*K)</th>
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Isobaric properties for Dodecafluoropentane

<table>
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<th>Temperature (C)</th>
<th>Pressure (MPa)</th>
<th>Density (kg/m3)</th>
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<th>Entropy (J/g*K)</th>
<th>Cv (J/g*K)</th>
<th>Cp (J/g*K)</th>
<th>Sound Spd. (m/s)</th>
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With back flow pipe we were able to reduce the max velocity through micro-channel to be 195.66 mm/s

1) Back flow pipe
2) Micro-channel
3) Condenser coil

P represents the pump (not shown in figure)

Direction of fluid flow in backflow pipe in 1 G

Direction of fluid flow in 1 G
Max velocity in micro-channel
195.66 mm/s

Direction of fluid flow in 1 G
Microchannel CFD (temperature)

Max temp in fluid at 195.66
48.14°C

Direction of fluid flow in 1 G
3-D model
Methods of data collection

Thermal DAQ

Accelerometer
Conclusion

• Better understand flow boiling through a micro-channel
• The changes in efficiency in varying gravity environments
• Determine force required to overcome film boiling in zero gravity (if possible)
• The effects of varying gravity on vaporized medium in a flow loop
The team

Mechanical Engineers
Philip Lane
Alvin Harvey
Kyle Edgerton
Angel Sanez

Civil Engineers
Sara Ruvalcaba

Chemical Engineers
Jessie Privett
Norann Calhoun

Electrical Engineers
Manda Mahender
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UpAerospace
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Resources


