Convection Heat Transfer of Nanofluids in Commercial Electronic Cooling Systems

N.A. Roberts and D.G. Walker

Department of Mechanical Engineering

Vanderbilt University

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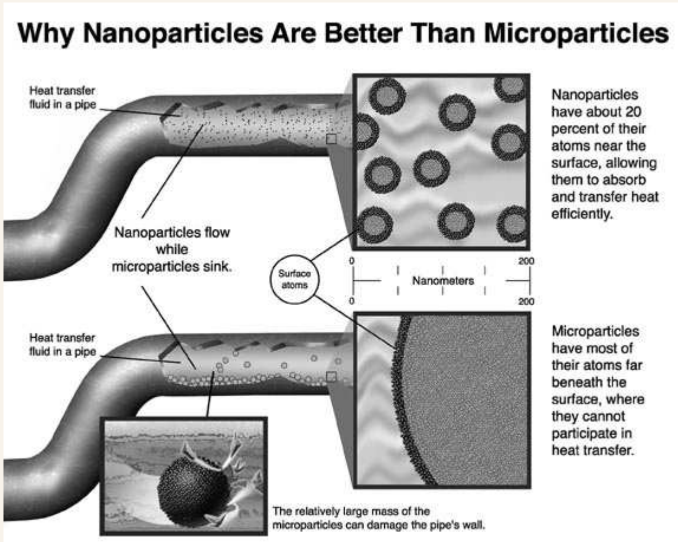
Introduction

Nanofluids are colloidal suspensions of nanoparticles in a base fluid

- Typical nanofluid properties
  - particles are metals, metal oxides or carbon in various forms
  - particles range in size between 1 and 100 nm
  - base fluid usually water and organic liquids
- Effects of nanofluids
  - *have shown an enhancement in thermal conductivity*
  - have shown enhancement in convective heat transfer in well controlled systems - can they be used in real systems
- Benefits of nanofluids
  - reduced sedimentation and viscosity
  - reduced damage to internal system components



http://www.anl.gov/Media Center/News/2004/nanofluidsbig.html

Why do nanofluids exhibit enhancement of thermal conductivity over effective medium theories?

1. Brownian motion results in micro/nanoconvection around particles
2. Ordering of liquid near the liquid/solid interface
3. Near field radiation between particles
4. No actual enhancement over theory, but a clustering into spherical or linear chains of particles while models assume well dispersed solutions

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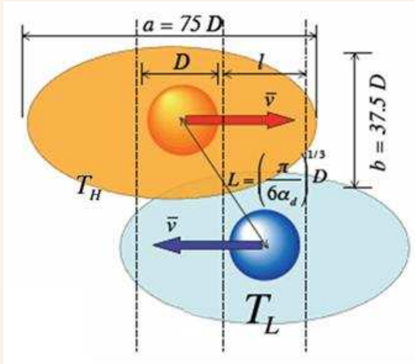

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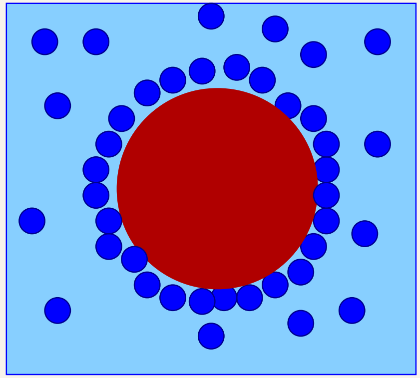

http://www.mae.ncsu.edu/research/ck CM-P Lab/nanoflow.htm

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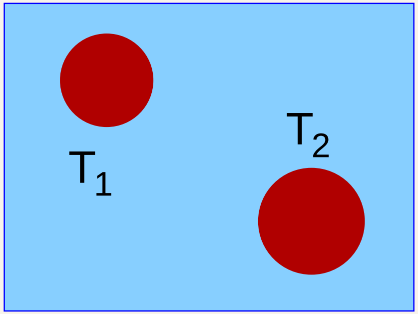

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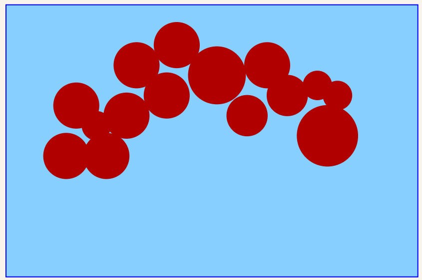
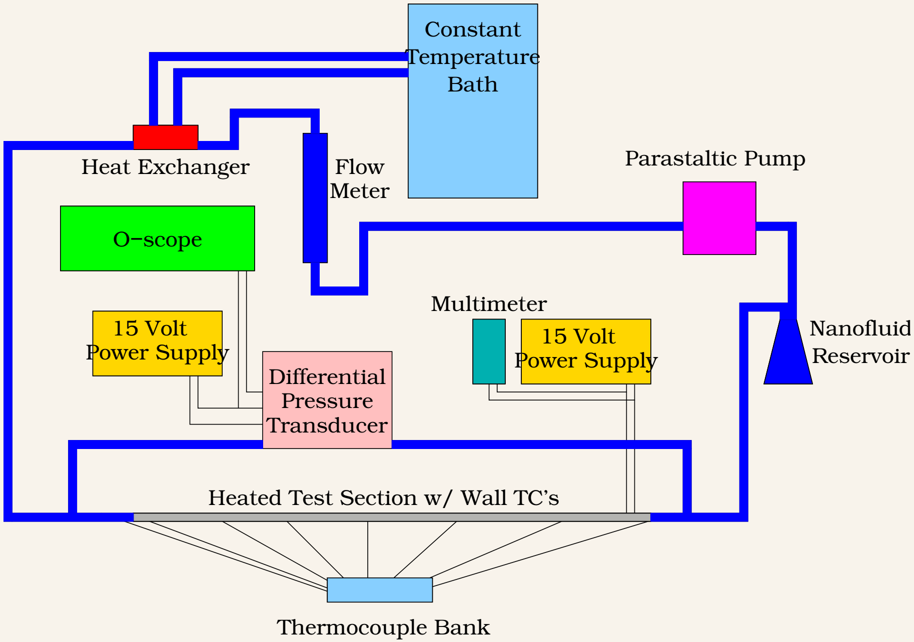


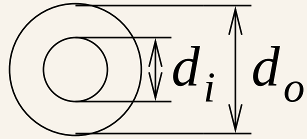
Experimental Setup

Straight Tube Setup



Test section properties

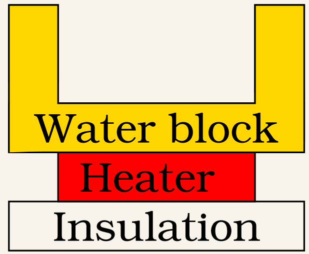
d_i (mm)	d_o (mm)	l (m)
1.07	1.47	0.91

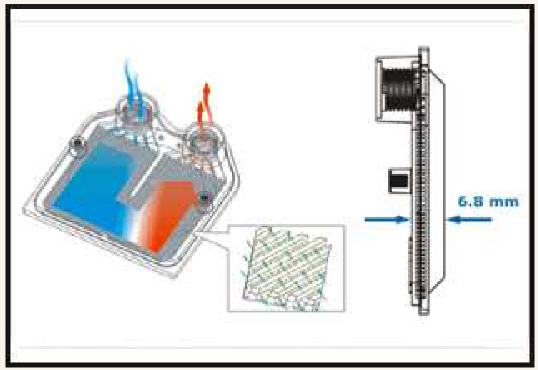


Key measurements

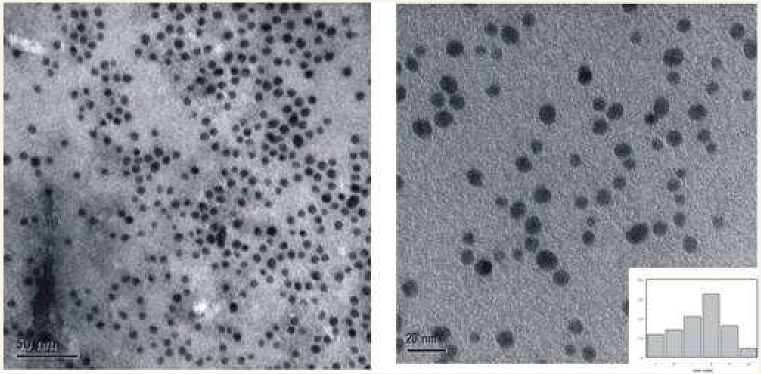
- pressure drop along test section
- temperature profile along outside of test section
- inlet and outlet fluid temperatures
- heat dissipation from heater wire
- volumetric flow rate

Commercial System Setup

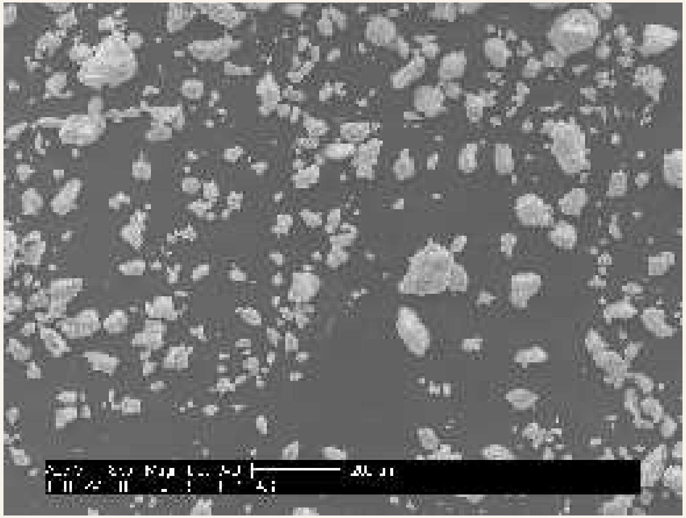




Nanoparticles and Preparation



http://miam.physics.mcgill.ca/miam/images/research/self assembly/lennox nanoparticle.jpg



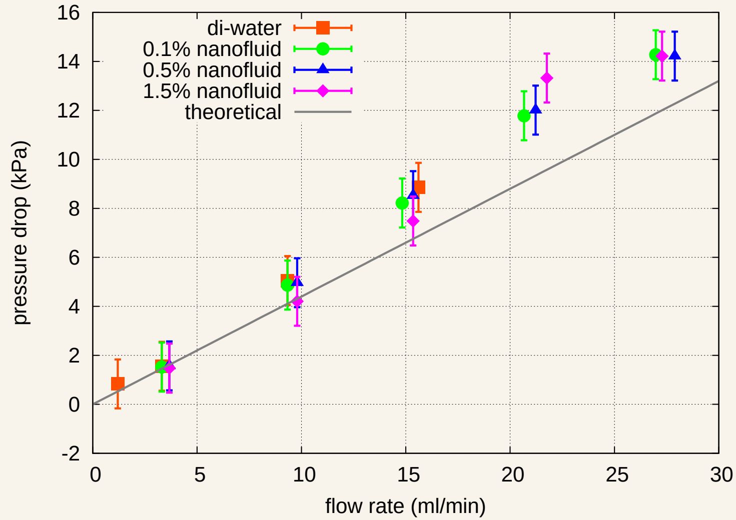
Lai et al., 2008

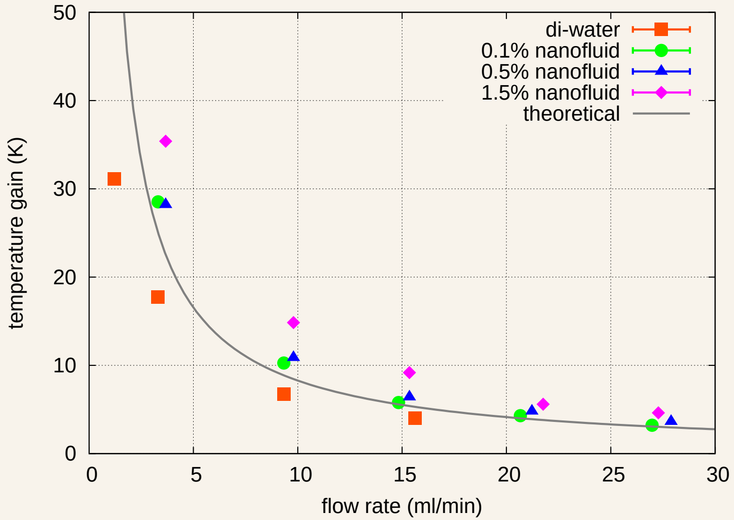
- Nanoparticles (Al_2O_3)
  - γ 10 nm
  - γ 20-30 nm
- Preparation
  - Nanoparticles are weighed and added to de-ionized water for different particle loadings
  - Nanoparticles are ultrasonicated for 1 hour to break up agglomerates
- Results from DLS

Particle (nm)	10	20-30
Ave. Part. Size (nm)	148.7	253.8
poly disp.	0.783	0.277

Results: Pressure and Temperature Drop/Increase

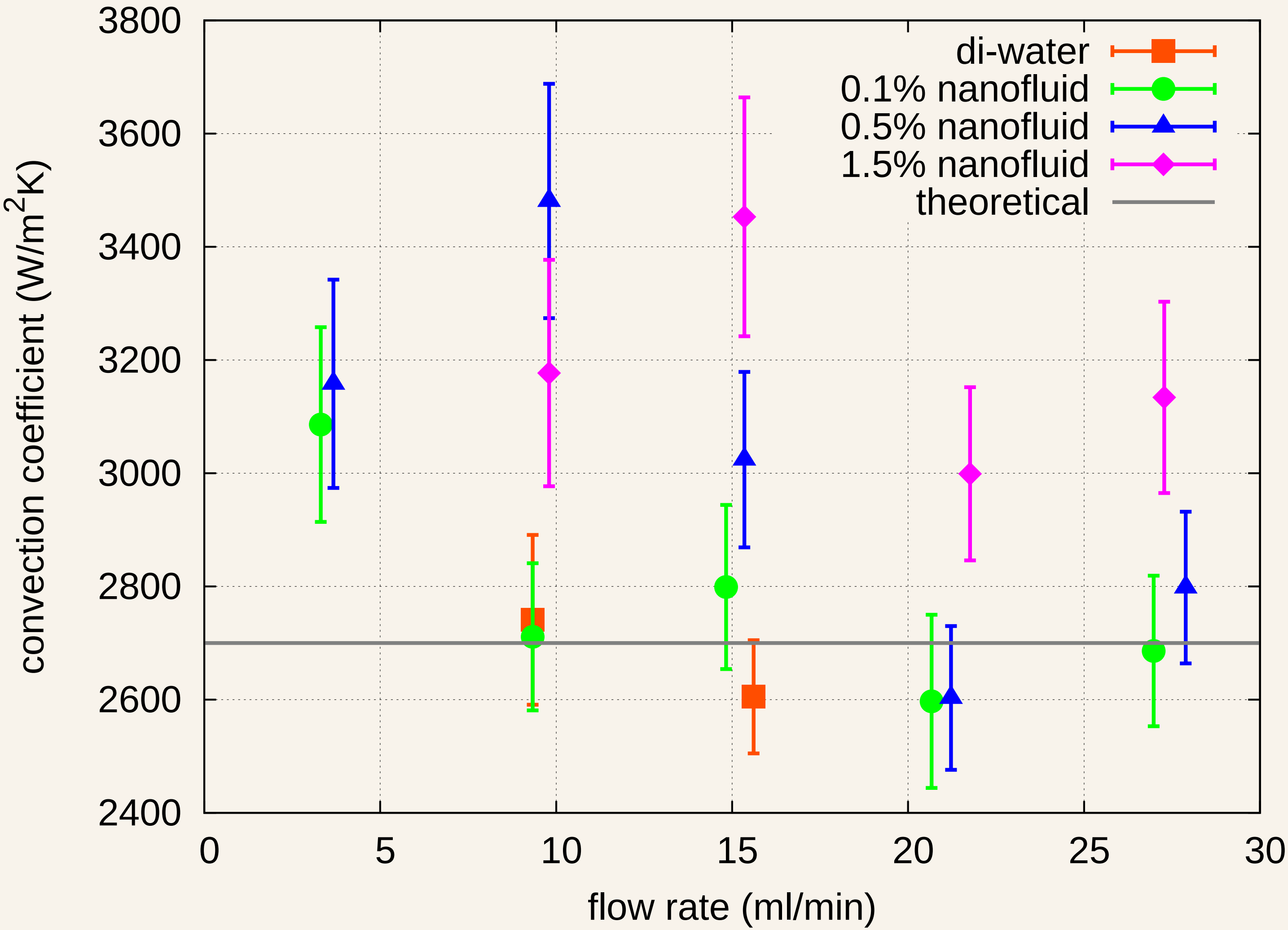
- Nearly equal pressure drop across the tube for all fluids
- Deviation from theoretical pressure drop for DI-water due to entrance effects and surface roughness



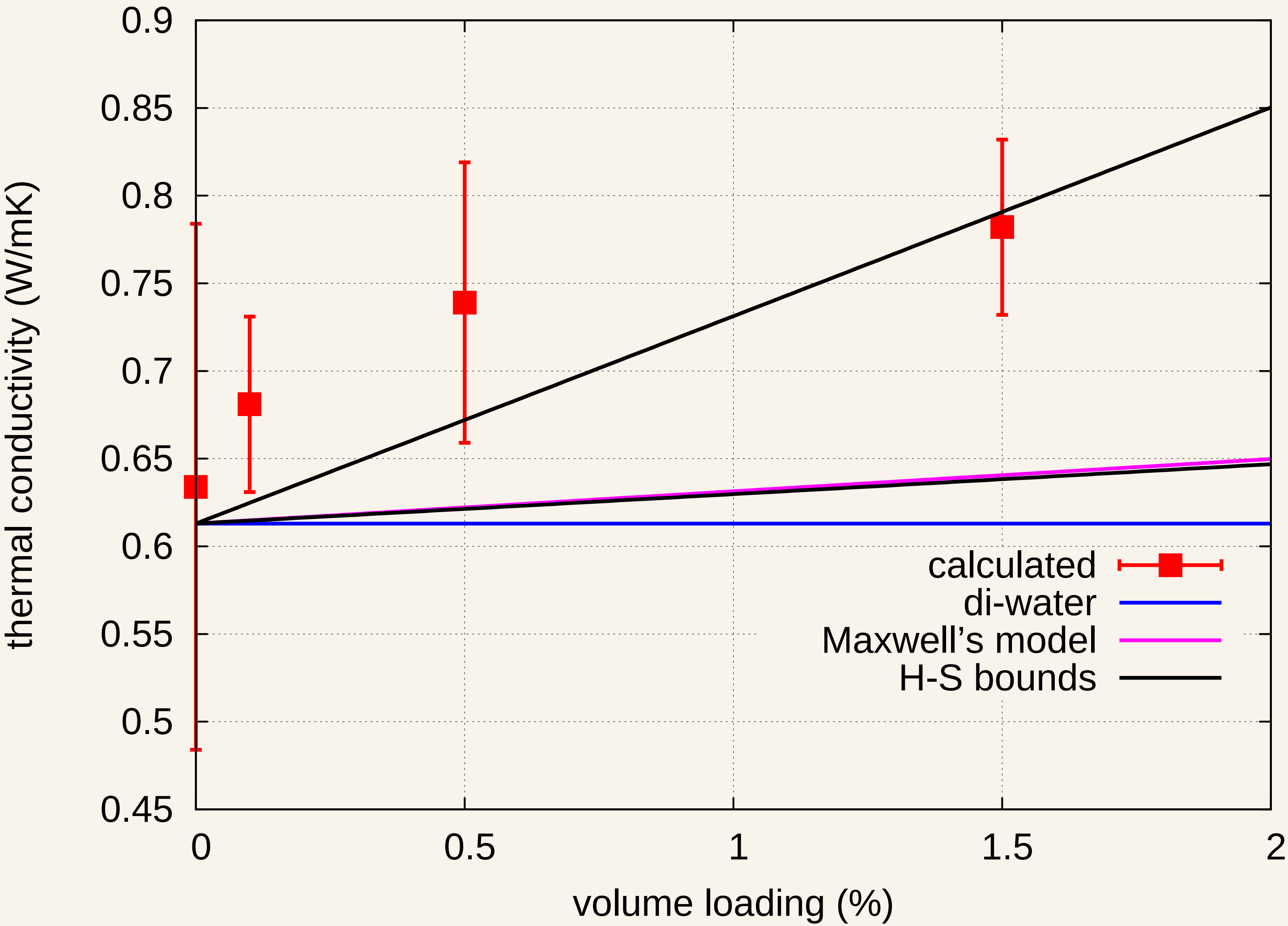


- Nearly equal temperature gain across the heated tube for the DI-water and the 0.5% nanofluid
- Greater temperature gain in the 1.5% nanofluid due to enhanced convective heat transfer

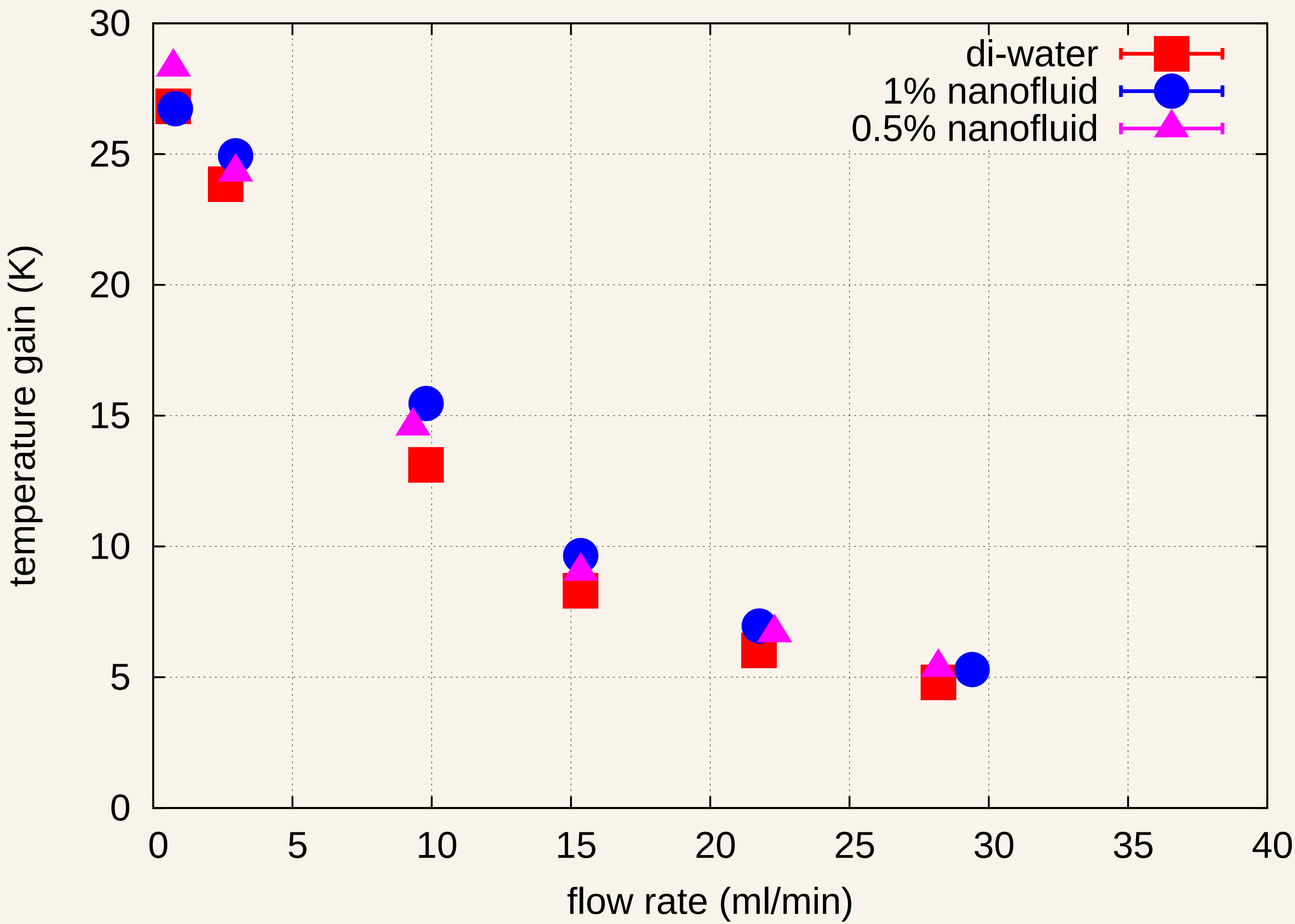
Results: Average Convection Heat Transfer Coefficients



Results: Calculated Thermal Conductivity



Results: Commercial System



Conclusions/Future Work

- Observed enhancement in convective performance without an increase in viscosity
- Calculated enhancement thermal conductivity with increasing volume loading within the Hashin-Shtrickman Bounds
- Keblinski's recent theory is supported by our results