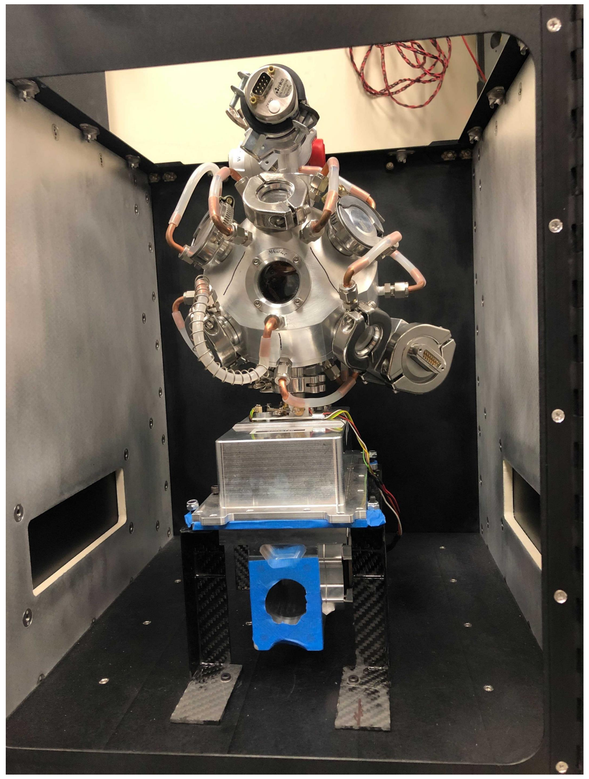
Precision Cooling Loop for Space Based Payloads

Samantha Rosenberg, Alexander Madison, Dr. Julie Brisset
Florida Space Institute, University of Central Florida

Introduction

Background:
- Small satellites (SmallSats) are used in both academia and industry as a platform for space based payloads
- Components on SmallSats are temperature sensitive and operate within small temperature ranges. Creating a need for precise thermal regulation.
  - Precision thermal regulation can be accomplished by using a precision cooling loop that regulates the temperature of the components within the operating range and dissipates excess heat

Dims:
- Dust In situ Manipulation System (DIMS) is a payload designed to make and manipulate dust clouds in low gravity environments to simulate early planet formation
- Currently DIMS is designed for use in a double payload locker on the Blue Origin New Shepard Rocket
- DIMS requires a consistent temperature of 23C +/- 0.1C and dissipation of 60W of heat
  - To maintain the temperature withing this range DIMS utilizes a precision cooling loop with deionized water as its working fluid.
- DIMS will be moved to a SmallSat platform in Low-Earth Orbit (LEO)
  - Deionized water will freeze in LEO on a SmallSat, so an alternative working fluid will need to be selected.
  - The size constraints of a SmallSat require modification to be made to the existing DIMS cooling loop



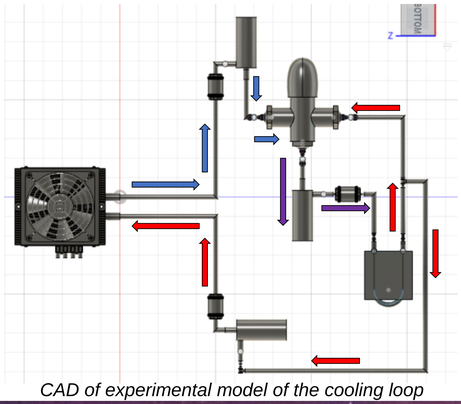
DIMS payload with experimental chamber (top) and dust injection unit (bottom)

Experiment Preparation

Cooling Loop Set Up:
- An experimental model of the DIMS cooling loop was designed in CAD

Pumps:
- Pump head was calculated
- Bernoulli's equation was used to find the head loss
- Minor loss was ignored, and head loss was set equal to major loss to calculate the length of tubing that should be used for turbulent flow for each pump.
- Based on these calculations tubing length was optimized and a new pumps was recommended

Sensor Calibration:
- Temperature sensors were calibrated using the Steinhart equation
- The date from the temperature sensors was compared to the temperature of a thermometer
  - This data was plotted, and a line of best fit generated to correct the sensor data



CAD of experimental model of the cooling loop

Fluid Selection

- Use figure of merit to select a fluid that will not freeze in LEO
- Compare suggested fluids based on flammability, radiation hardness, obtainability, toxicity, etc.

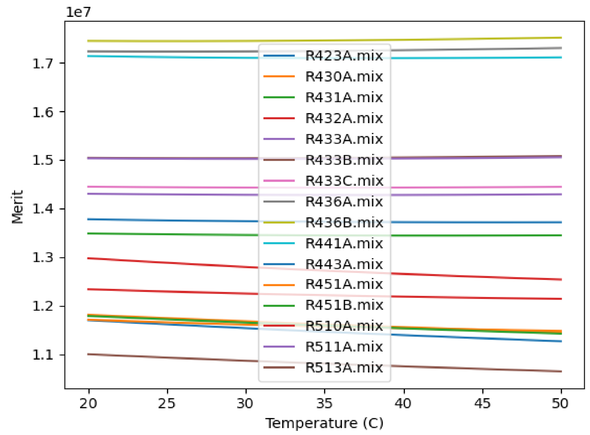
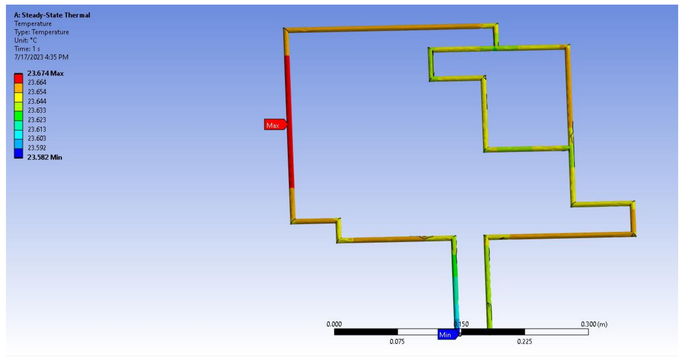


Figure of merit for a single-phase cooling loop with low pressure drop, excluding ethylbenzene

Experiment

Setup:
- Each test will run for five minutes which is the length of one experiment on the DIMS payload
- Each time a new component or change is added to the cooling loop a pilot test (no cooling or heating) will be conducted
- Three runs with heating and cooling will be conducted after the pilot test

Data:
- The data collected in the pilot test will serve as a baseline for comparison of data collected in the heated/cooled runs
- The data collected from the heated/cooled test will be used to identify areas of improvement in the cooling loop setup
  - Design changes are modeled in CAD and simulated in Ansys Fluent



Ansys simulation of heat transfer through simplified cooling loop model pilot test

Future Work

Single phase cooling loop:
- Conduct test on single phase cooling loop with working fluid identified from figure of merit
- Pick new pumps for cooling loop based on design criteria and working fluid properties

Two-phase cooling loop:
- Create figures of merit for a two-phased cooling loop
- Construct theoretical model for a two-phased cooling loop
- Compare date from two-phased cooling loop to data from single phased cooling loop

DIMS:
- Integrate modified cooling loop onto DIMS payload

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