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IER 296: Preparations for MOX Experiments with IRSN

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IER 296

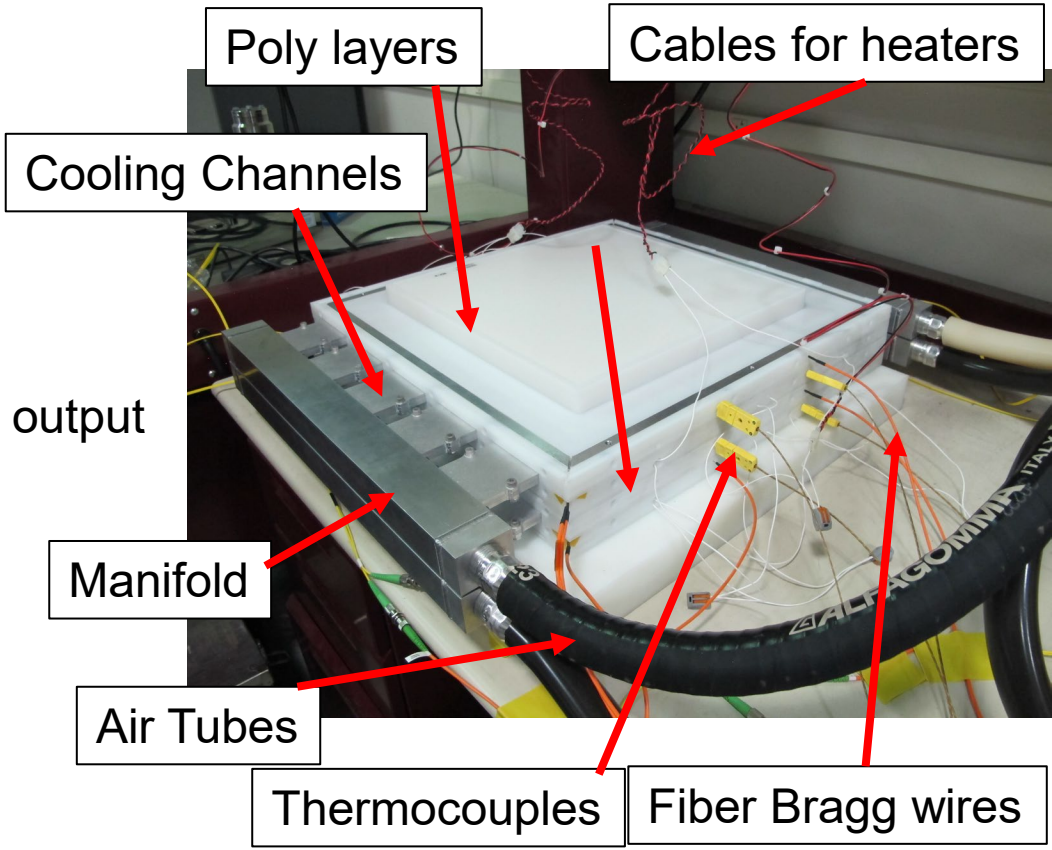
- TEX-MOX
  - Vaibhav's talk just before this
- Joint program with LANL, IRSN, and LLNL
- This talk is focused on prototype testing

Prototype Testing - Goals

- Test cooling solution
  - Should be noted that cooling is nota safety requirement, it is to get better data
- Test temperature measurement systems
  - Thermocouples and Fiber-Bragg system
- Measure temperature difference with ambient
- Measure temperature gradient within the assembly (goal is <15°C)
- Measure time to reach steady state for different scenarios
- Determine optimal strategy for cooling the system
  - E.g. fan duty cycle, whether fans should be controlled individually for each layer, whether fans should be turned on when adding layers.

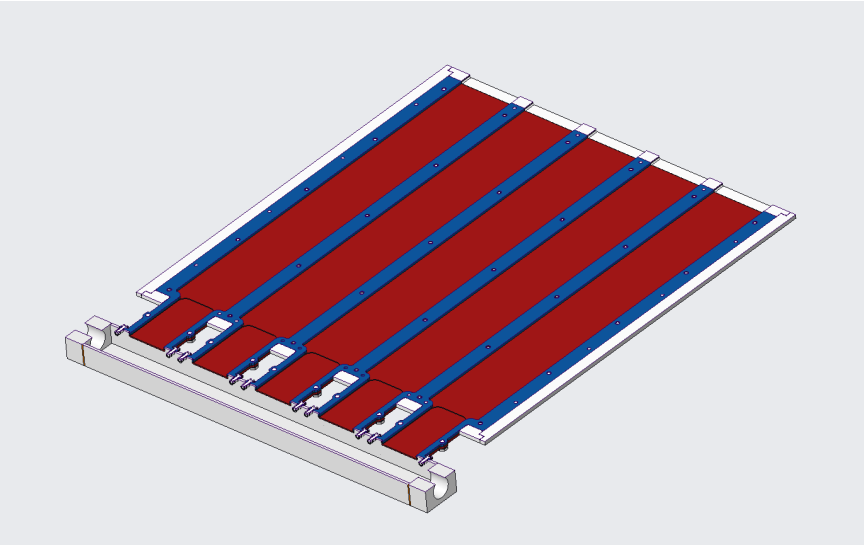
Prototype Testing - Overview

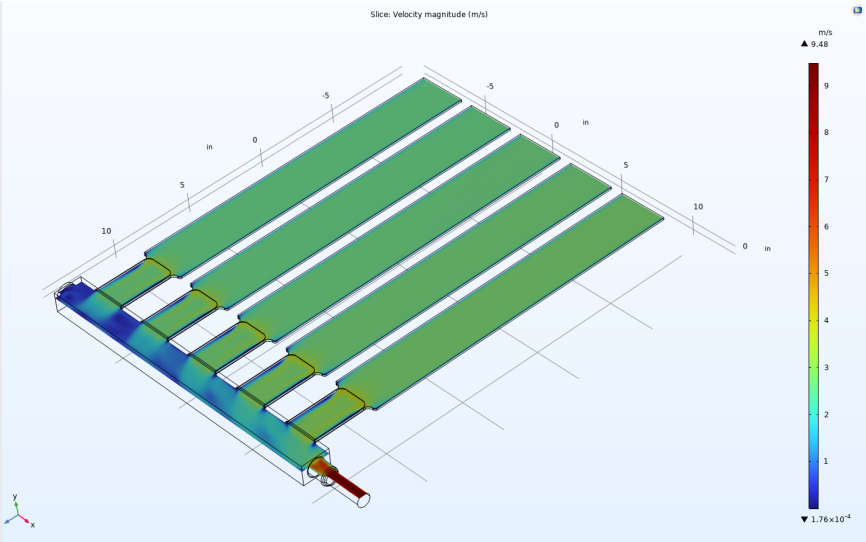
- Four Layers – Inter1 configuration
- Each layer has it's own:
  - Air cooling
  - Heaters
  - Thermocouples
- Heaters were tuned to match heat output of ZPPR plates (PUMN or PUMH)



Prototype Testing - Overview

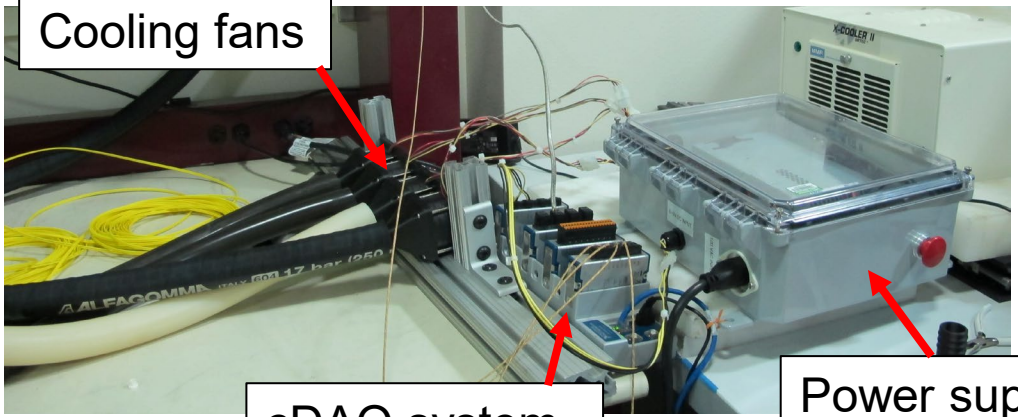
- Air cooling is done by sucking air through the system, to a manifold, through a tube, to an electric fan
- There are air channels under where the fuel will be placed – experiment designed to remove as much excess heat as possible





Prototype Testing - Overview

- Each fan can be controlled individually – meaning flow rate for each layer can be adjusted individually
- Heaters were powered with a BK Precision power supply
- Thermocouple Data collection and fan control used National Instruments cDAQ modules and custom LabView software



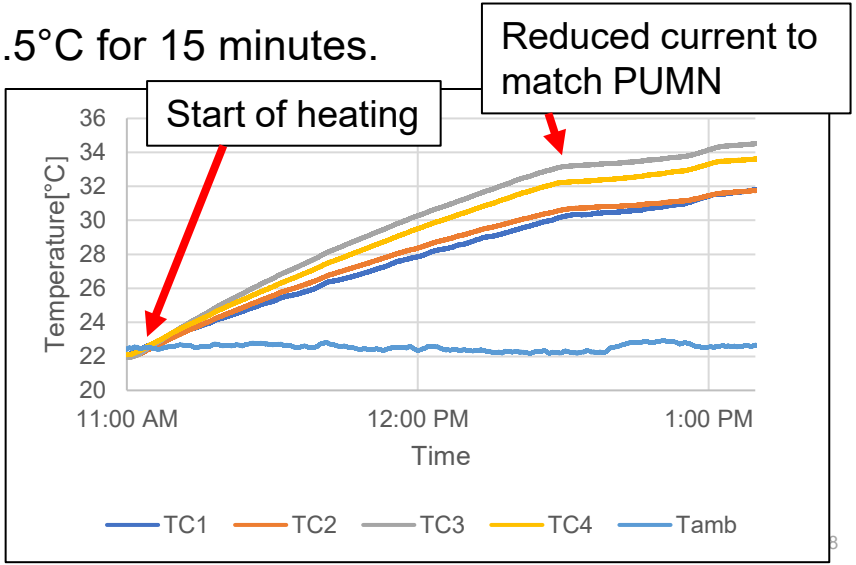
Overview of individual tests

- Configuration 1: Simulating a Full PUMN Assembly
- Configuration 2: Simulating a 1/M Mockup of Full PUMN Assembly
- Configuration 3: Simulating 2 PUMN, 2 Partial PUMH layers
- Configuration 4: Simulating a Cooling Failure Test

Configuration 1: Simulating a Full PUMN Assembly

- PUMN Layer Power Generation: 22.934 W
- Power was turned on and set to ~28 W per layer during initial heat up to aid in faster heat-up time. Still took ~2.5 hours to reach steady state.
- Once the assembly neared steady state, power generation per layer was adjusted to match PUMN (22.934 W)
  - Steady state defined as temperature within 0.5°C for 15 minutes.
- Measured temperatures at steady state:

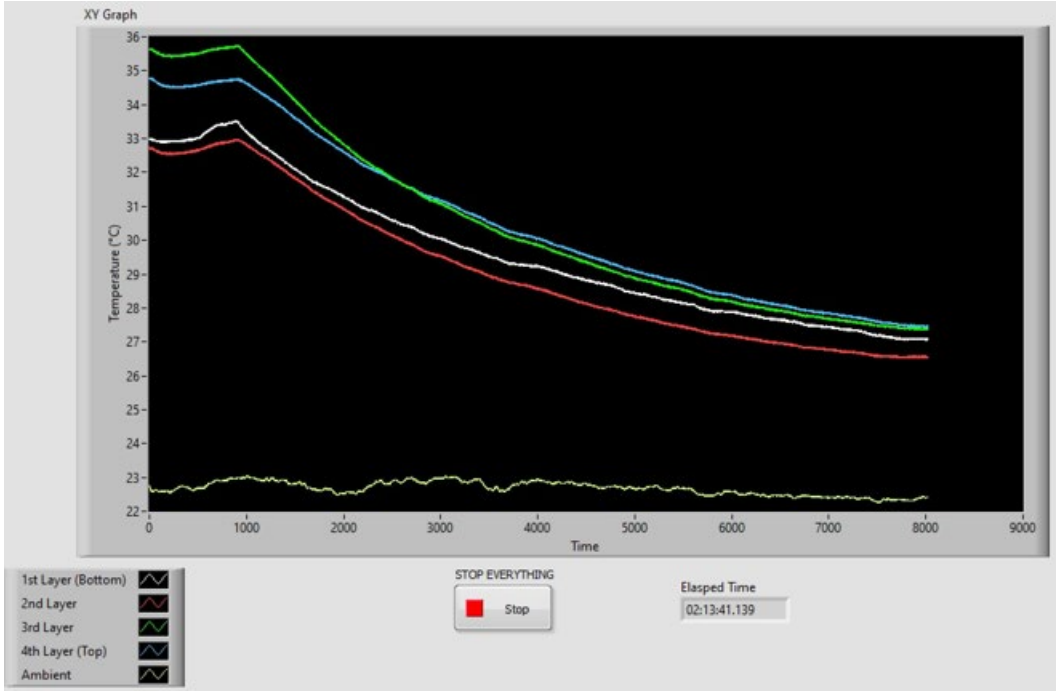
Layer	Temperature [°C]
Layer 1	33.0
Layer 2	32.8
Layer 3	35.5
Layer 4	34.8
Ambient	22.8



Configuration 1: Simulating a Full PUMN Assembly

- Fans turned on to 60% duty-cycle
- Steady state at 60% duty cycle reached in 2 hours and 2 minutes
- Measured temperatures:

Layer	Temperature [°C]
Layer 1	27.0
Layer 2	26.8
Layer 3	27.5
Layer 4	27.5
Ambient	22.5



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Configuration 1: Simulating a Full PUMN Assembly

- Fans then turned to 100% duty-cycle
- New steady state at 100% duty cycle reached in 1 hours and 30 minutes
- Measured temperatures:

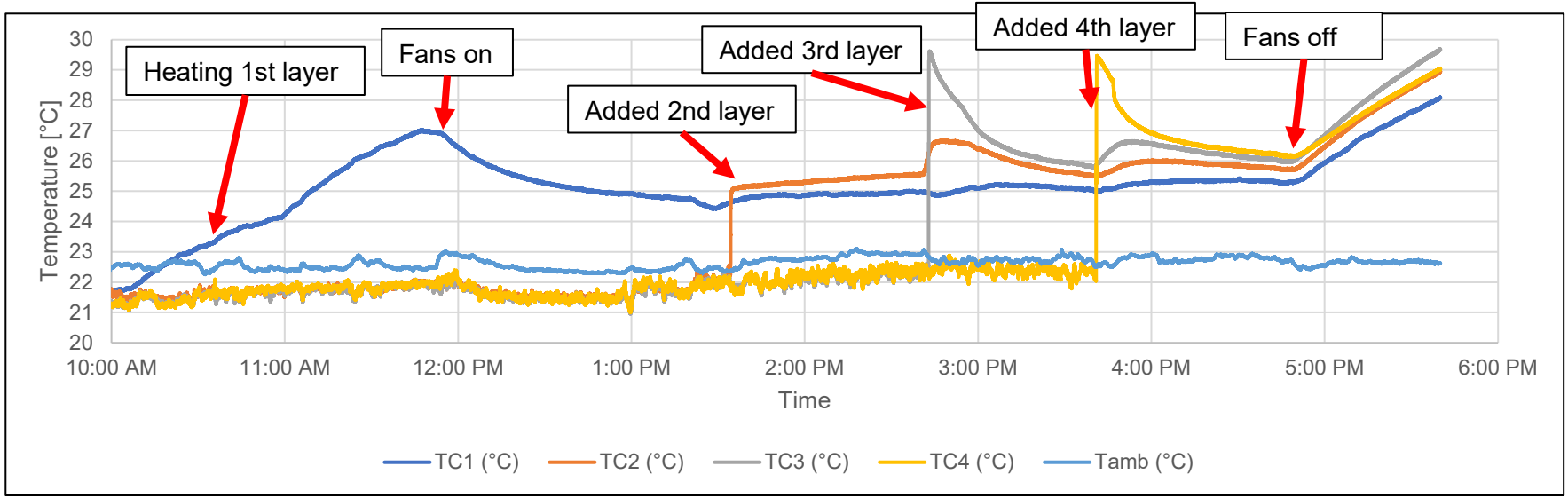
	Fans off	60% Duty Cycle	100% Duty Cycle
Layer	Temperature [°C]	Temperature [°C]	Temperature [°C]
Layer 1	33.0	27.0	25.8
Layer 2	32.8	26.8	25.6
Layer 3	35.5	27.5	26.2
Layer 4	34.8	27.5	26.4
Ambient	22.8	22.5	22.75

Configuration 1: Key Results

- Final temperatures only 3°C above ambient
- Final temperature gradient less than 1°C
- 60% fan duty cycle met design requirements
- However, it was advantageous to always run fans at 100%
  - Will result in less time needed for cooling and slightly lower temperatures
- Communication was lost with cDAQ twice – after some trouble shooting throughout the week, this issue was resolved.
  - One of the big benefits of thorough testing!

Configuration 2: Simulated 1/M Mockup of Full PUMN Assembly

- Instead of starting with all four layers, layers were added one at a time, with the layer to be added ‘pre-heated’ with a separate heater.
- New layers were added when the new steady state was reached

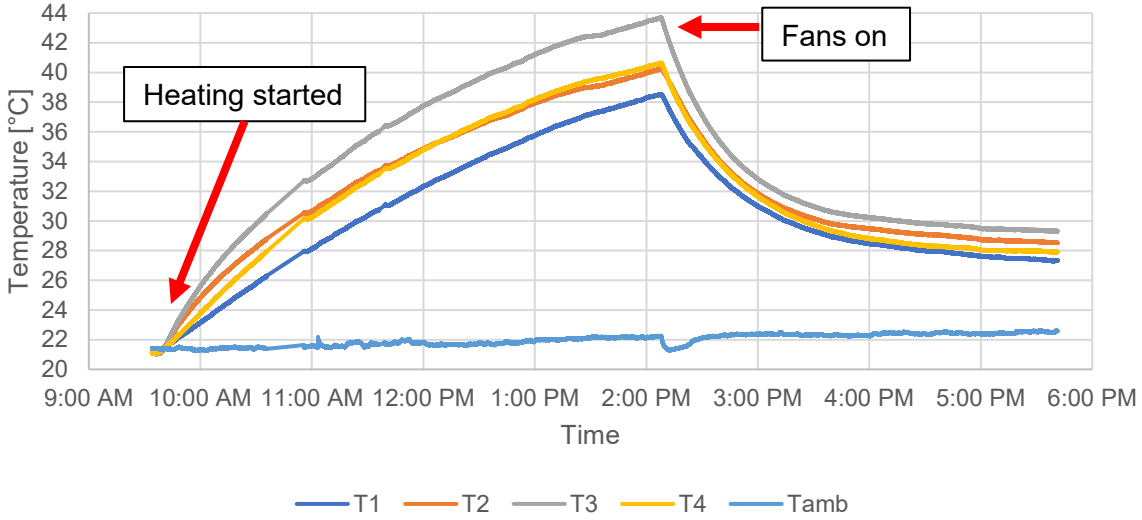


Configuration 2: Simulated 1/M Mockup of Full PUMN Assembly

- Once each layer was added and fans were turned on, it took 60-75 minutes per layer to reach the new steady state.
- With all four layers, results were similar to Configuration 1 (as expected).
  - 2.6°C above ambient and less that 1°C temperature gradient.

Configuration 3: 2 PUMN, 2 Partial PUMH layers

- More representative of the Thermal case of IER 296.
- PUMN Layer Power generation: 22.9 W
- Partial PUMH Layer power generation: 51.2 W
- Total power: 148.2 W
- PUMH layers in center
  - Highest worth region in the experiment, and most conservative from a testing standpoint as they are the most insulated layers



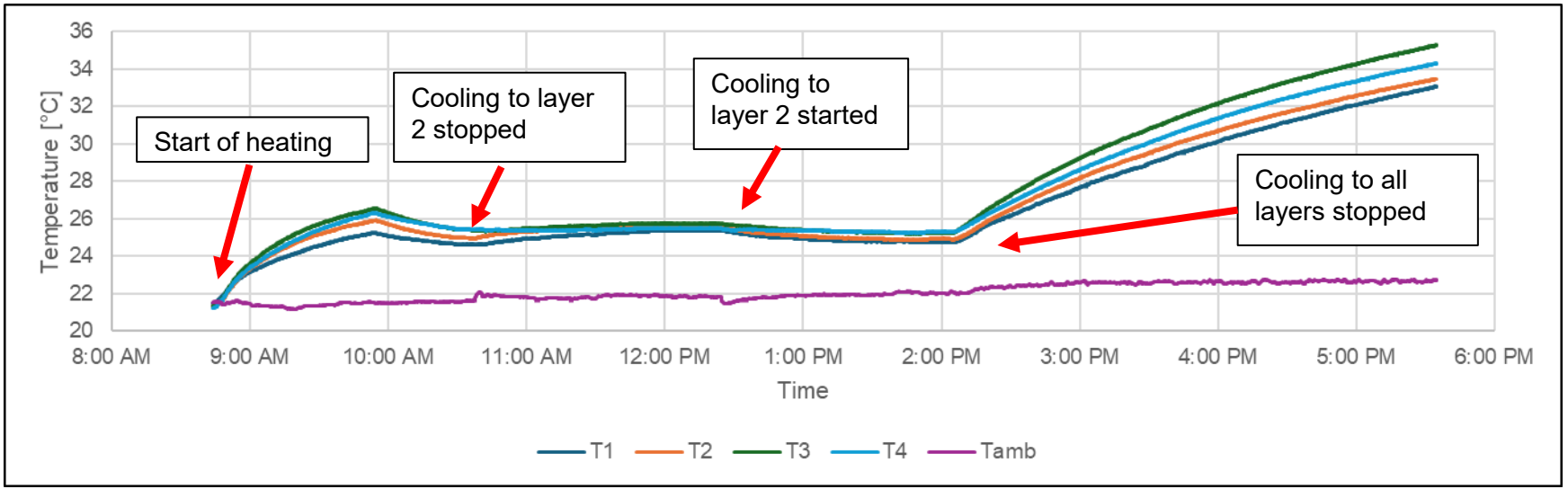
Configuration 3: 2 PUMN, 2 Partial PUMH layers

- Due to time constraints, fans were started at 2 pm, before reaching steady state – this is after 6 hours of heating
- 4.7°C max temperature above ambient, temperature gradient of 2°C

	Max temperature fans off	Steady state fans on
Layer	Temperature [°C]	Temperature [°C]
Layer 1	38.5	27.3
Layer 2	40.3	28.6
Layer 3	43.7	29.3
Layer 4	40.5	27.9
Ambient	22.1	22.6

Configuration 4: Simulated Cooling Failure Test

- Steady state was reached with fans on, then cooling to layer 2 was stopped.
- After 90 minutes, cooling was restarted for layer 2
- After reaching steady state, cooling to all layers was stopped



Configuration 4: Simulated Cooling Failure Test

- Cooling failure for a single layer has little impact on the experiment
  - Change of 1°C for layer 2 with and without cooling
- Layers near the membrane can not be cooled due to space constraints, so this gives a good picture of expected temperatures for those layers.
- There was not enough time to reach steady state with fans off at the end of the day.

Summary of Results

- 3 - 3.5 hours to cool to steady state if the assembly is hot prior to turning fans on
- 60-75 minutes for each additional layer to reach steady state
- Temperature above ambient was better than expected
- 100% duty cycle recommended
  - Fans are quite loud, so hearing protection is recommended when 10+ fans are running – NCERC has hearing protection available
- Features to be added to the LabView program were identified and will be incorporated before experiment execution

Test Configuration	1	2	3	4
T1 [°C]	3.1	2.6	4.7	2.7
T2 [°C]	2.8	3.0	6.0	2.8
T3 [°C]	3.5	3.3	6.7	3.1
T4 [°C]	3.7	3.4	5.3	3.2
Max above ambient [°C]	3.7	2.6	4.7	2.7
Gradient [°C]	0.8	0.8	2.1	0.6

Acknowledgments

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