Air Cooling Preliminary Measurements

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EIC Weekly Meeting

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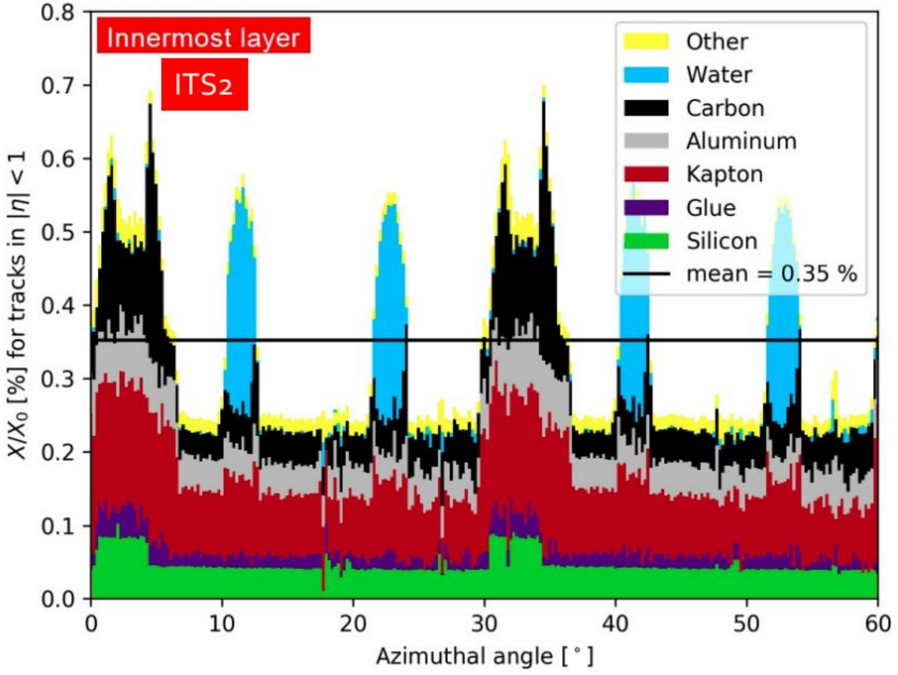
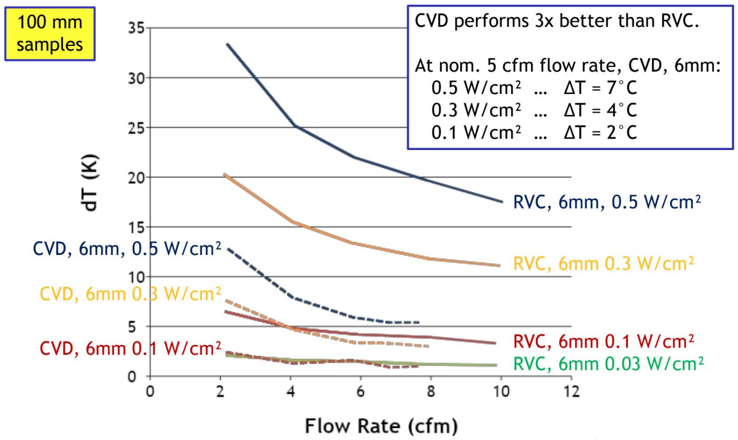
Motivation

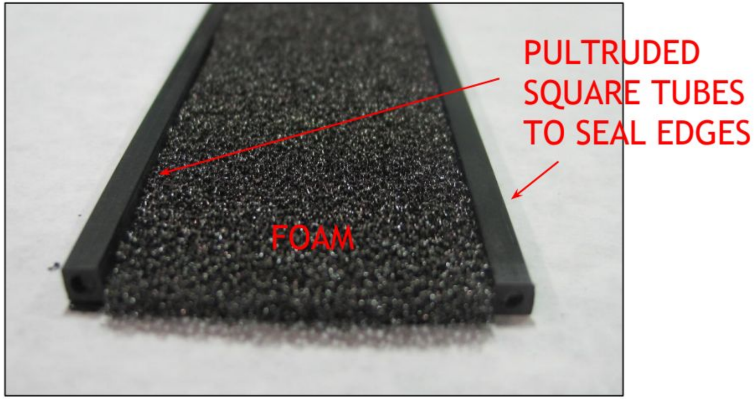
- An effort to lower the material budget
- Use air cooling instead of water cooling
  - Liquid coolant adds a decent amount to the material budget
- Questions
  - Is air effective enough?
  - Is our design stable enough to withstand air being blown at it?
- Repeat the previous LDRD before testing specifics to EIC R&D



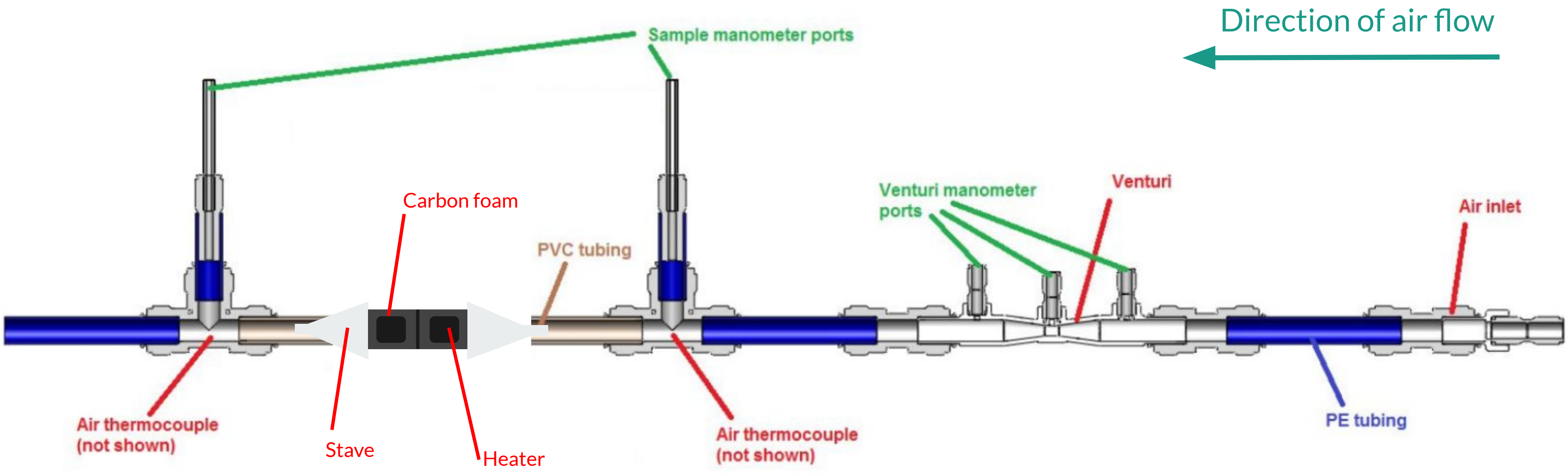
Previous LDRD

- Performed by LBL Engineering Division
- Built staves with different carbon materials/lengths/ppi
- Measured the pressure and temperature differences for each of the staves
- Our Goals:
  - Familiarize ourselves with their setup
  - Understand the results for the next set of measurements we want to take

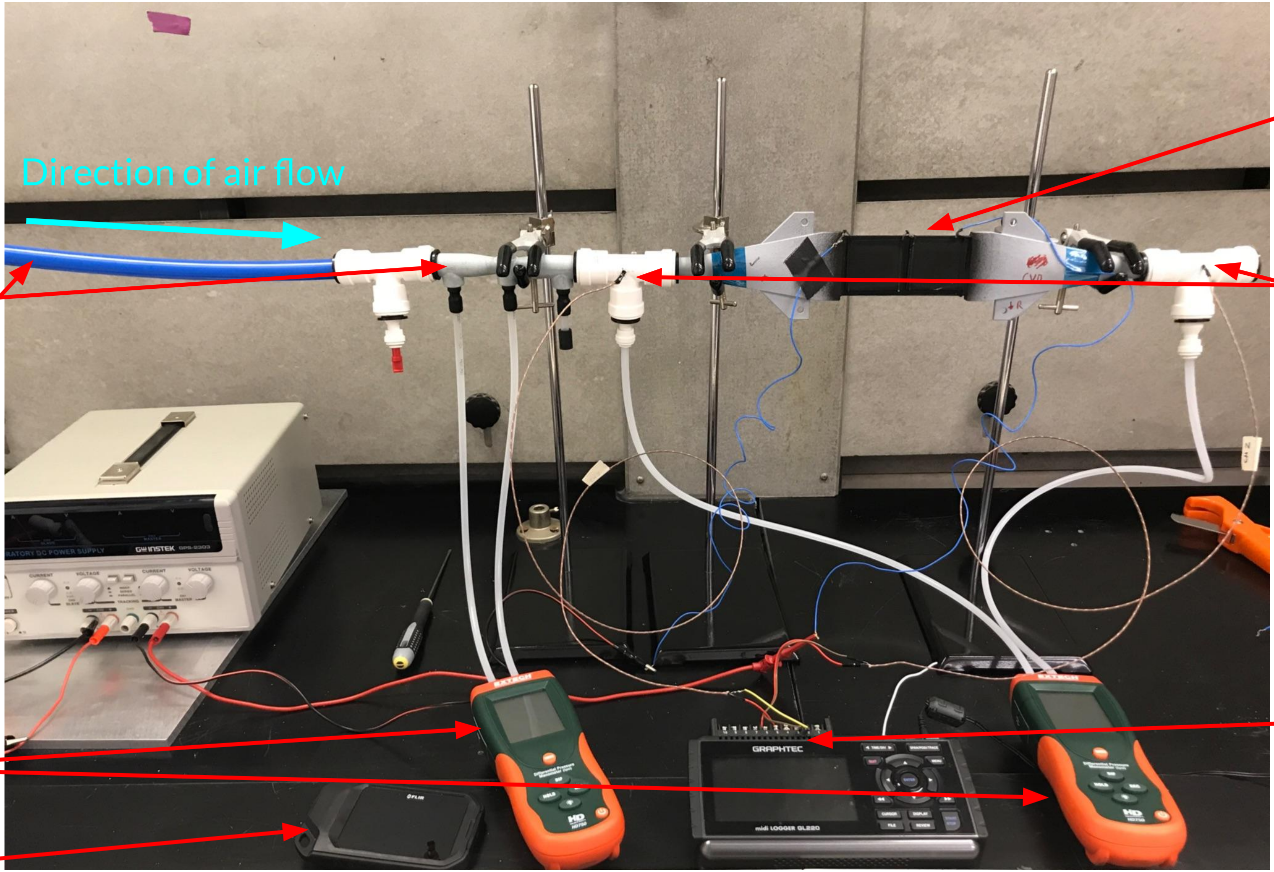




Schematic Setup (Updated)



Setup



Stave w/ C foam pieces

Venturi

Thermo-couples

Air Flow

Power Supply

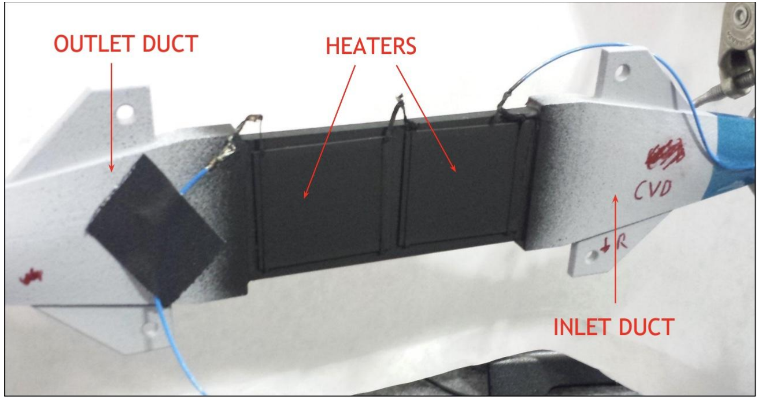
DAQ

Manometers

FLIR camera

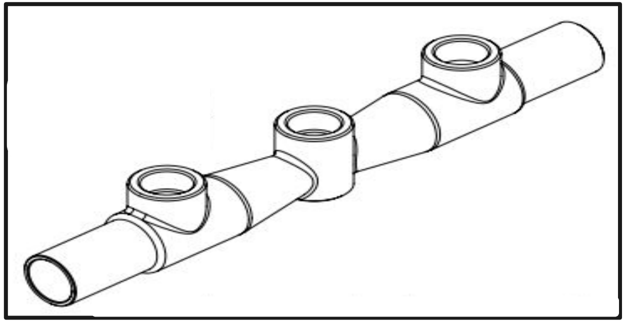
Types of Carbon Foam Staves

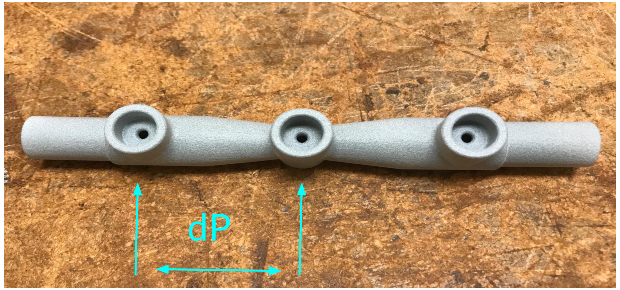
- Chemical Vapor Deposition (CVD)
- Reticulated Vitreous Carbon (RVC)



Type	Length (mm)	# of Si Heaters	Foam ppi	Thickness (mm)	Width (mm)
CVD	100	2	30	4	40
RVC	100	2	30	4	40
RVC	100	2	30	6	40
RVC	~500	8	45	6	40

Venturi





The pressure difference across the venturi and the application of continuity equations and Bernoulli's equation allow us to determine the volumetric air flow, Q.

Continuity Equation:

$$Q = v_1 A_1 = v_2 A_2$$

Bernoulli's Equation:

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2$$

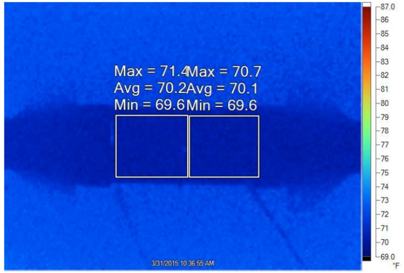
$$v_1 = \sqrt{\frac{2}{\rho} * \frac{(p_1 - p_2)}{(\frac{A_1}{A_2})^2 - 1}}$$

$$v_2 = \sqrt{\frac{2}{\rho} * \frac{(p_1 - p_2)}{1 - (\frac{A_2}{A_1})^2}}$$

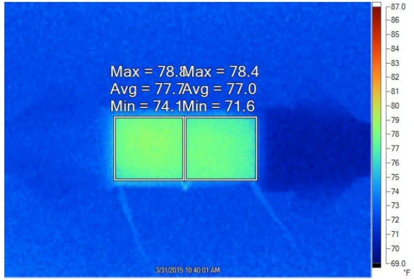
Procedure

- Send air at different velocities through the setup (from wall → venturi → stave)
- Use the power supply to warm up the heaters
  - The heaters can be set to have a constant voltage or a constant power density
- Take temperature and pressure measurements at positions before and after the stave
- Measure pressure using manometers
- Measure temperature differences using DAQ and FLIR camera
  - dT = bright temperature - dark temperature
- Air flow can be calculated across the venturi given the pressure difference and areas

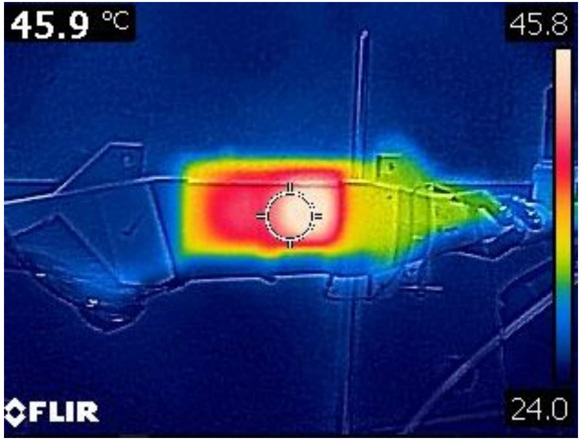
Dark – heaters off



Bright – heaters on



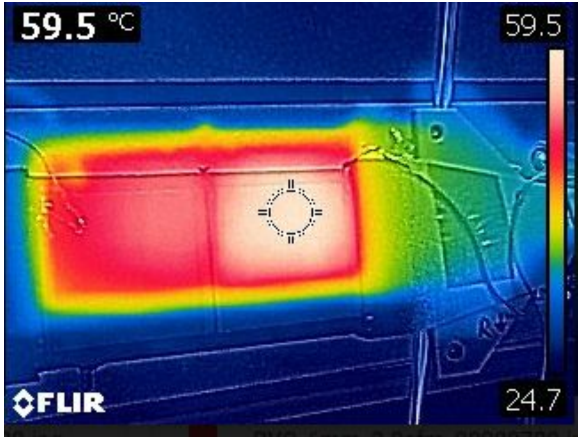
Heat Maps

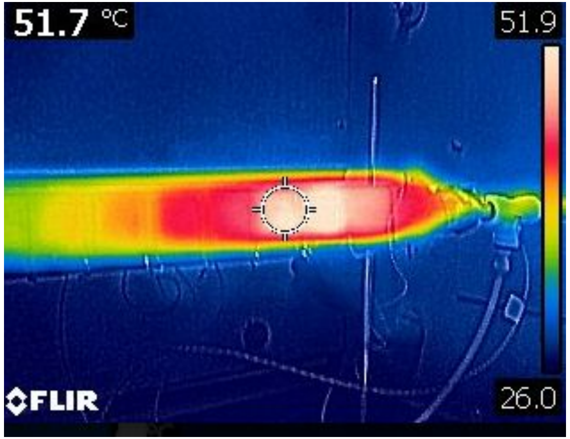


RVC 100mm 4 mm
3 cfm

At power density of 0.5 W/cm^2

RVC 100mm 6 mm
3 cfm





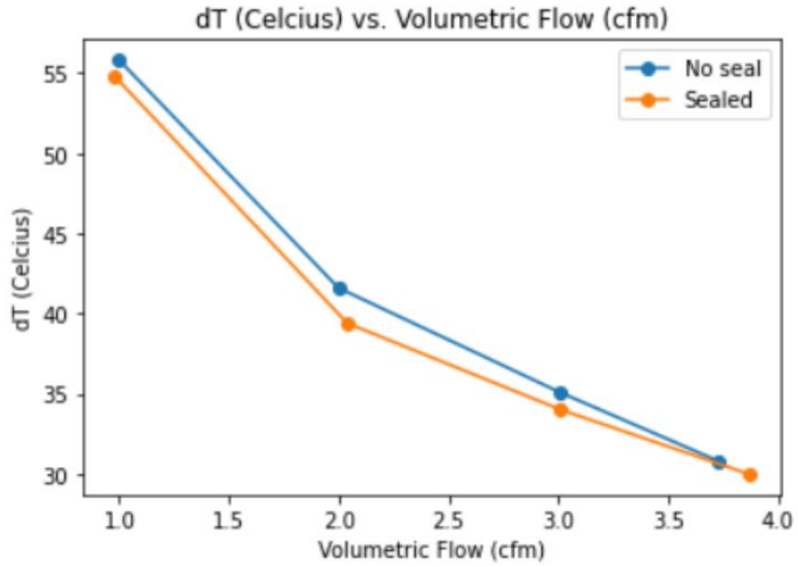
RVC 0.5m 6mm
3 cfm

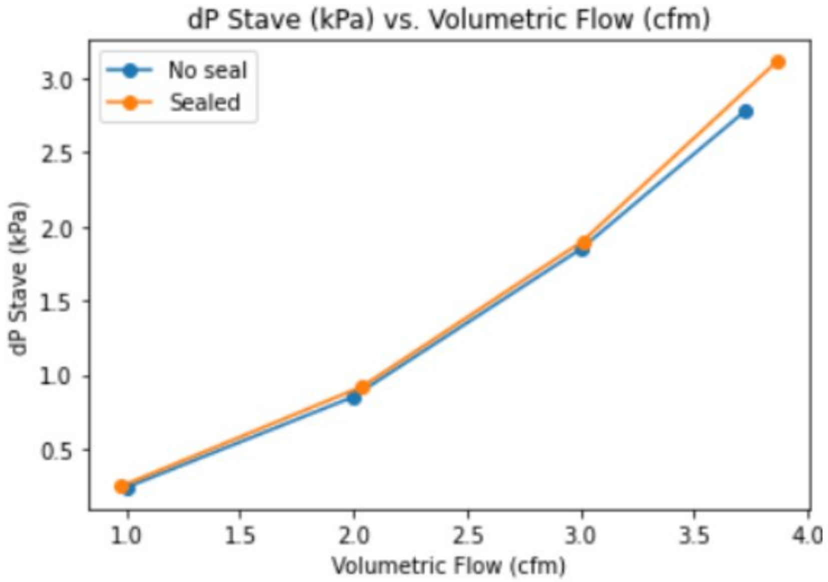
Progress

- Find the voltages that work best to give us the power density we want (0.5 W/cm^2)
- Seal all air leaks, glue any necessary pieces together
    - Compare how much better the sealed pieces perform
- Take measurements of the temperatures, pressures, current at different air flows (constant voltage)
    - Can currently only get about 3-4 cfm air flow without an amplifier
- Adjust the voltage to achieve a constant power density and retake all measurements

Sealed vs not sealed setup

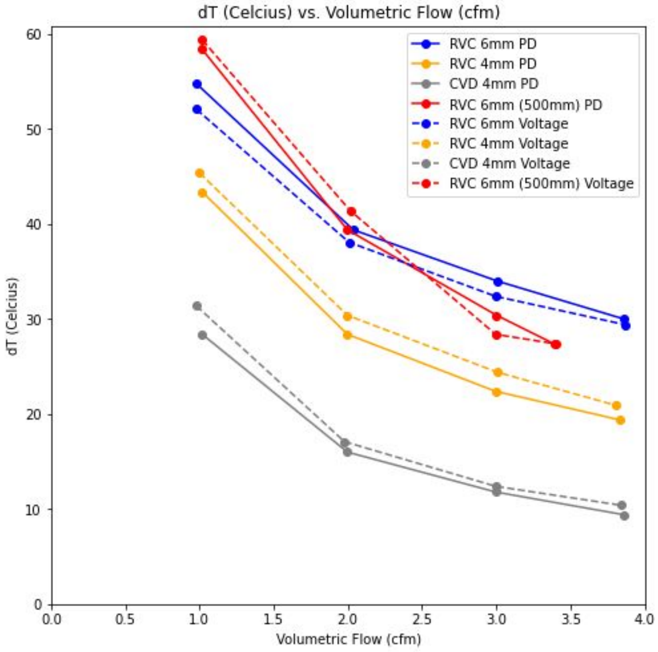
*not sealed setup refers to our setup before we added epoxy and adhesive to secure the venturi connections and the holes for the thermocouples

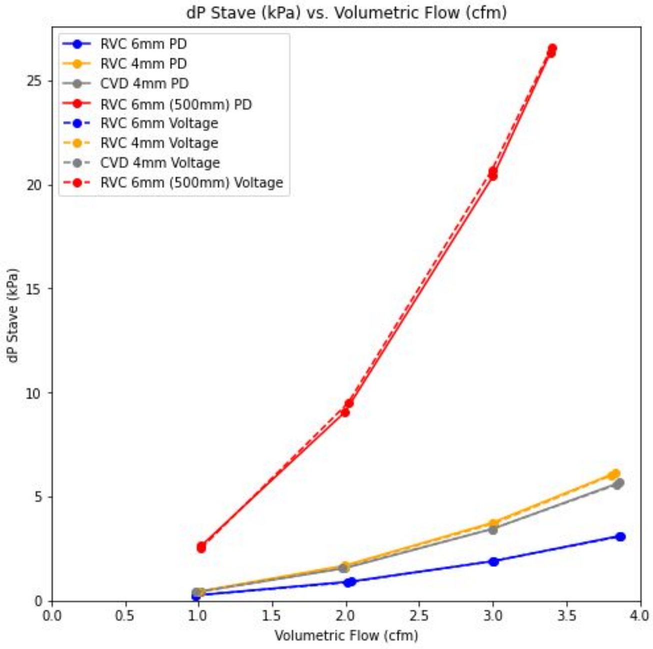




RVC 6mm stave

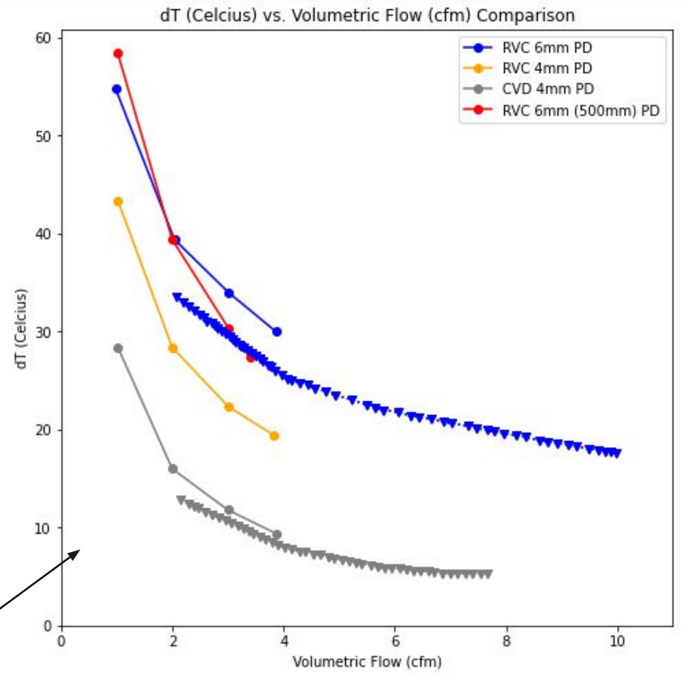
dT and dP vs Q (Power Density = 0.5W/cm²)





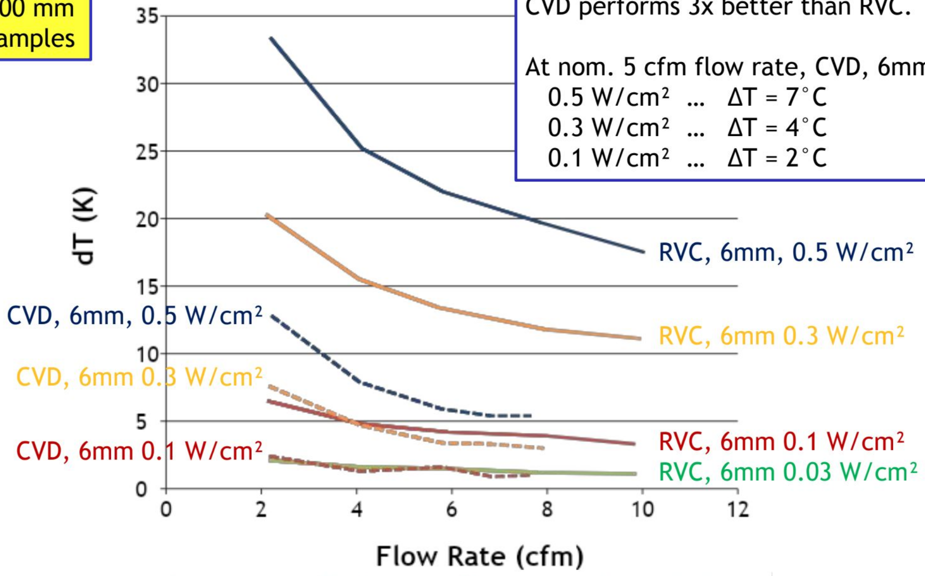
- Plots comparing constant power density with constant voltage
- We want to find the optimum value where we can get a $\Delta T < 10$ K, and a $\Delta P < 1$ bar

Comparison to LDRD Results - Temperature



0.5 W/cm^2

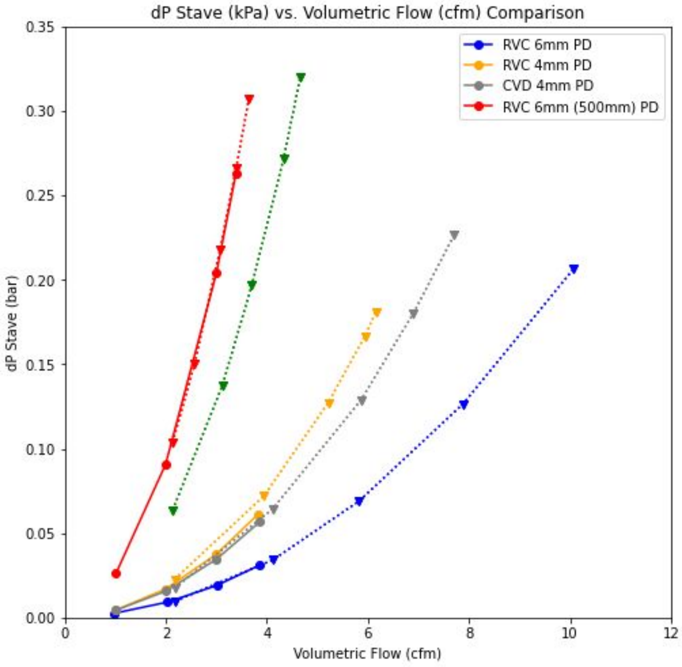
100 mm samples

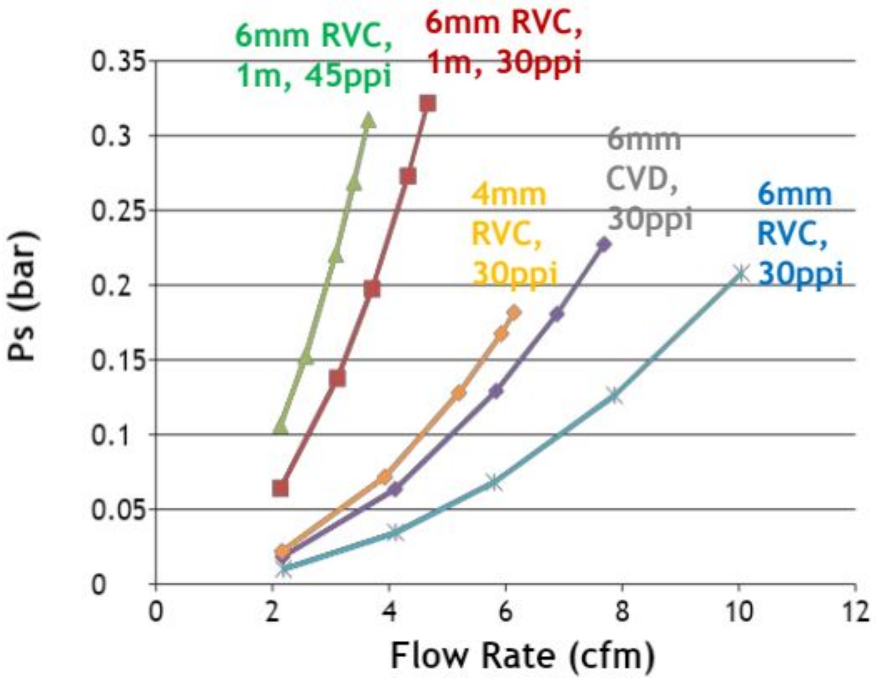


CVD performs 3x better than RVC.

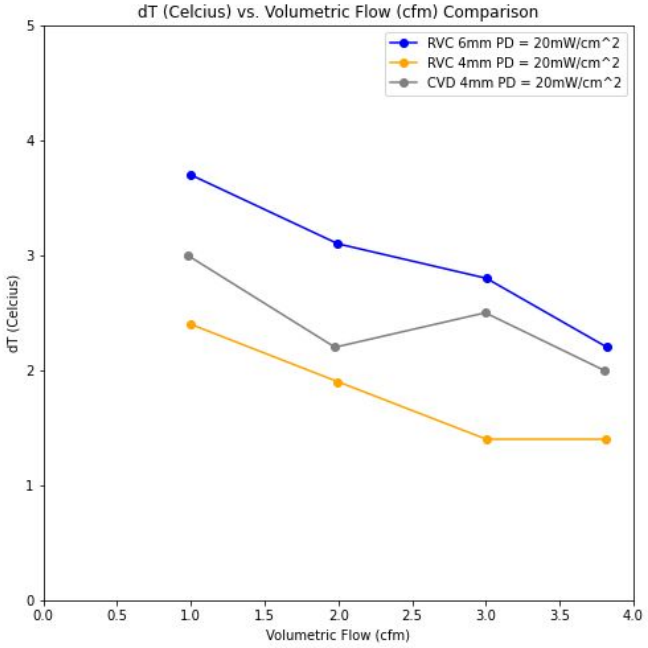
At nom. 5 cfm flow rate, CVD, 6mm:
- 0.5 W/cm^2 … $\Delta T = 7^\circ C$
- 0.3 W/cm^2 … $\Delta T = 4^\circ C$
- 0.1 W/cm^2 … $\Delta T = 2^\circ C$

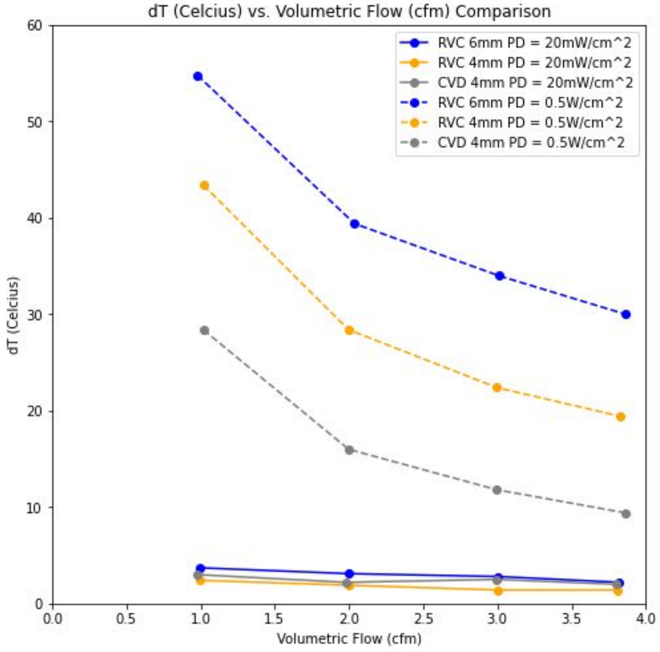
Comparison to LDRD Results - Pressure





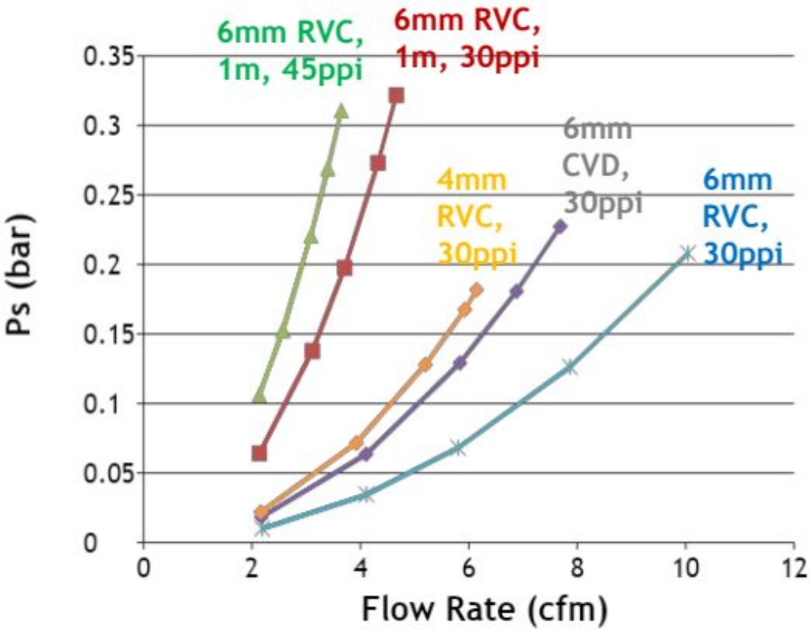
dT vs Q (Power Density = 20mW/cm²)





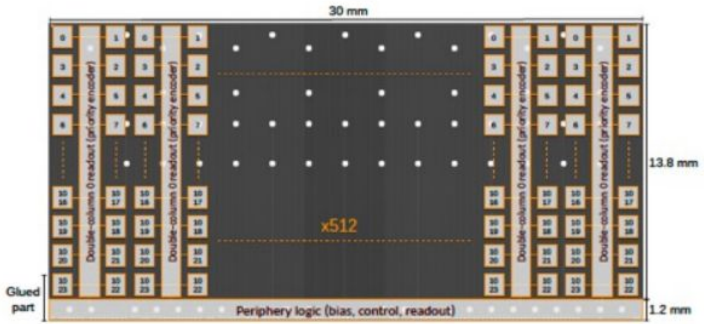
Air Amplifier

- Should be able to increase our air flow to ~10cfm
- Can compare to previous measurements done by LBL
- Currently having difficulty getting an air flow > 6.7 cfm
- Looking into other possible solutions (compressed air?)



Immediate Future Steps

- Use the air amplifier to increase air flow
    - Want to get up to 10 cfm
- Adjust power to 20 mW as a test for the pixel matrix
- Test higher power densities to imitate the periphery of the chip
- Use the stave without heaters to make a more realistic periphery & matrix heater
- A new heater with sense wires on it has been ordered
    - Will give better temperature measurements



Future Steps with an Engineer

- Look into designing a way to direct the air in a more material budget friendly way
- Make more realistic looking staves
- Make more realistic disc shapes

Conclusions

- Setup is mostly complete and working nicely!
- Air leaks and attachments have been securely sealed
- Preliminary measurements following the LDRD have been taken
  - Our results behave similarly to theirs!
- Now that we are familiar with the setup and procedure, we are moving forward with measurements at different power densities and thinking about improvements
- Once we are able to input a higher air flow, we will also take a greater range of measurements