Multi Channel Corrugation Studies

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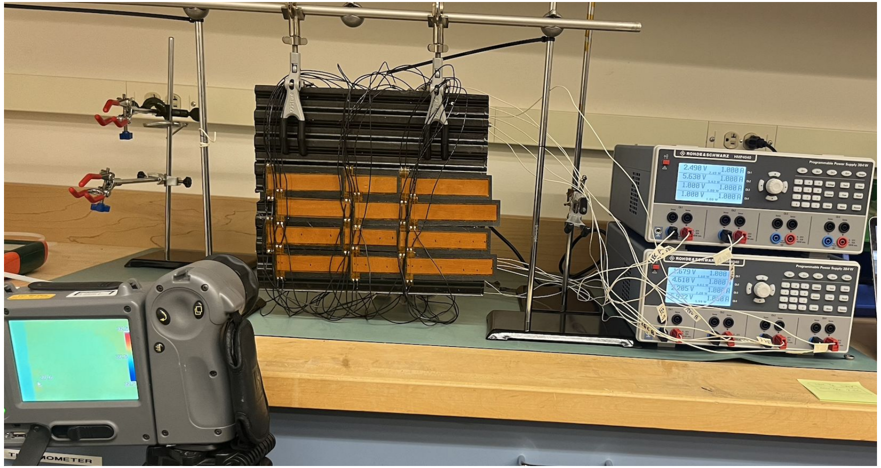
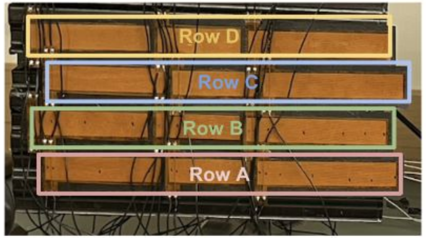
LBNL EIC Meeting
8/12/25

Questions of Interest

What have we quantified?

1. How neighbors on the **same side** impact temperature
2. How neighbors on the **opposite side** impact temperature
3. How **variable power** impacts temperature
4. How **forced convection** impacts temperature

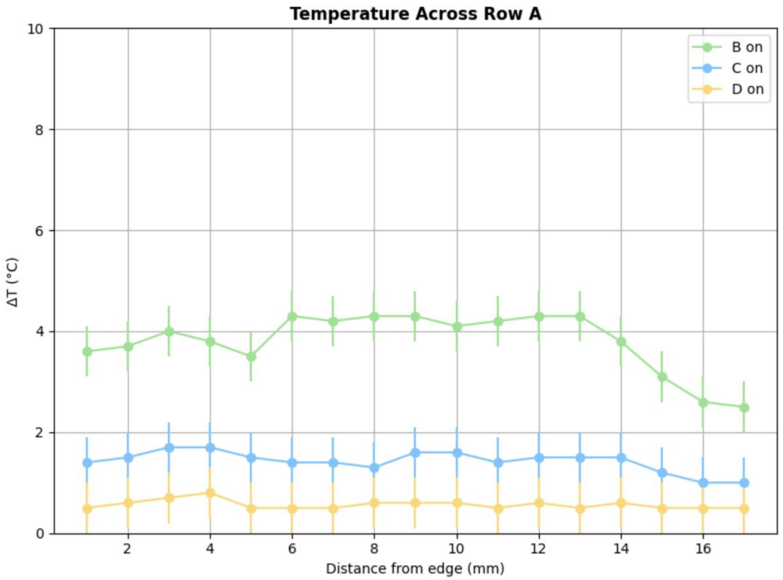


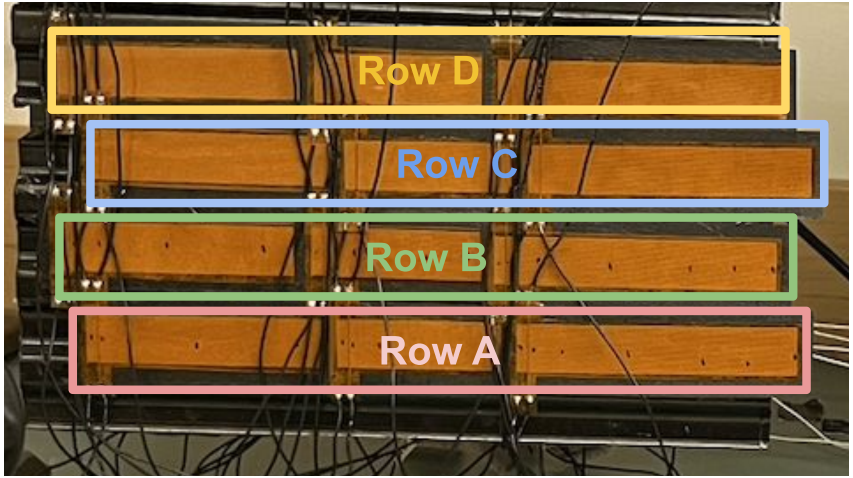


Nearest + Next To Nearest Neighbor

Measurements were taken across **Row A**

- Last component needed for a full model of **one side** of the corrugation is the impact of neighbors
- Measured with **Row A turned Off**, and at **MAX** power





Modelling with a Decay Function

$$\Delta T_x(n) = T_{0,x} \cdot e^{-n/\lambda}$$

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Amplitudes: [ 9.59670679  9.94378493 10.83413852 10.40933837  9.45417368 11.19692674
 10.96832389 11.14326254 11.40147178 10.94426608 10.96832389 11.31540203
 11.28299648 10.17238778  8.28155305  6.9663993   6.73779645]
Shared decay length λ: 1.0237208085396297
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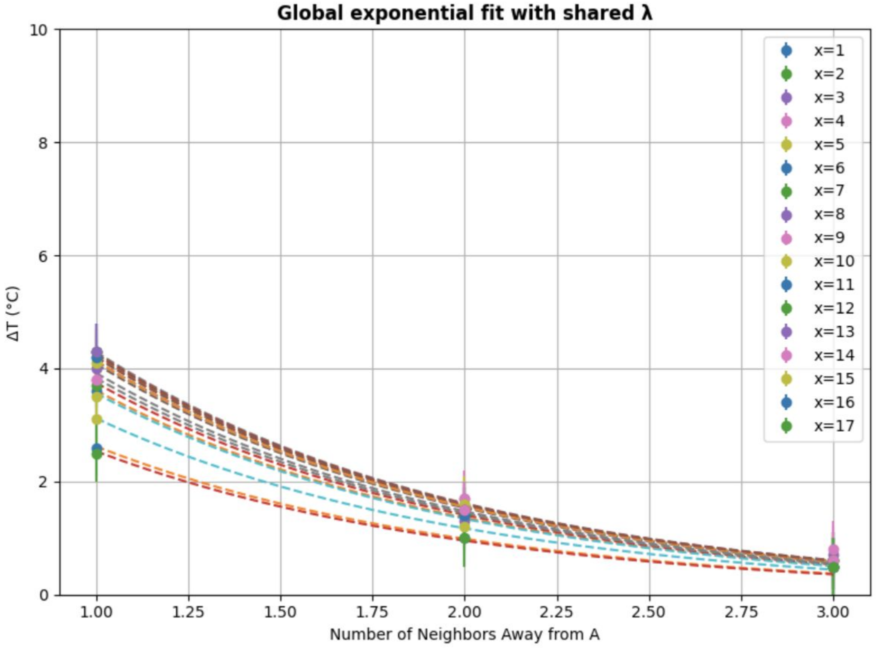
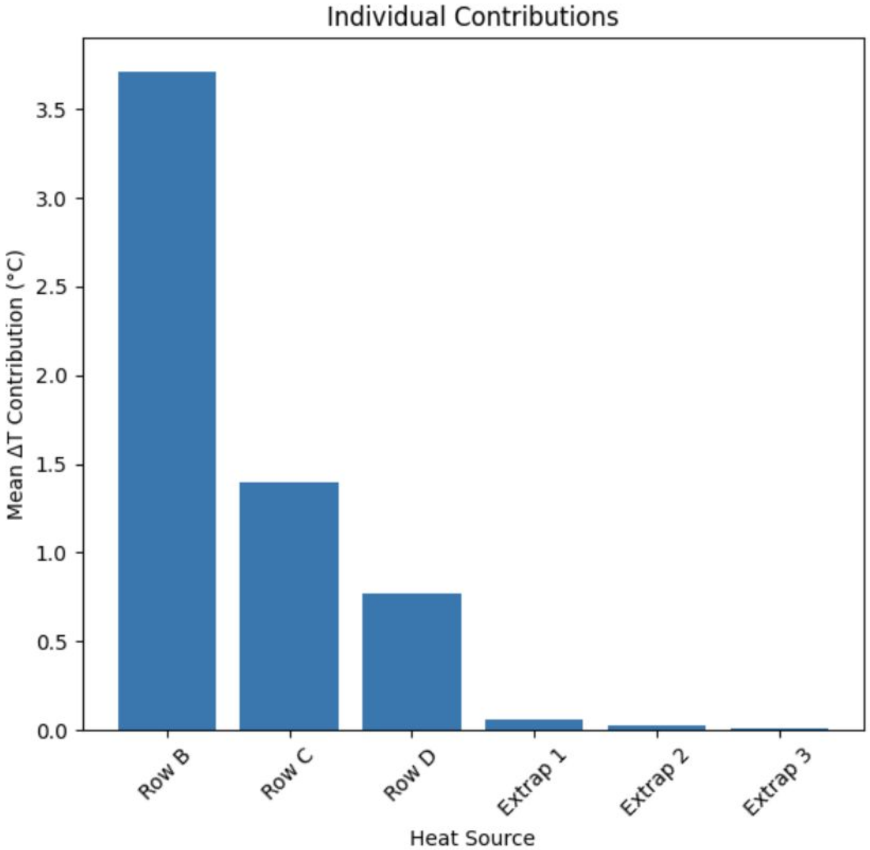
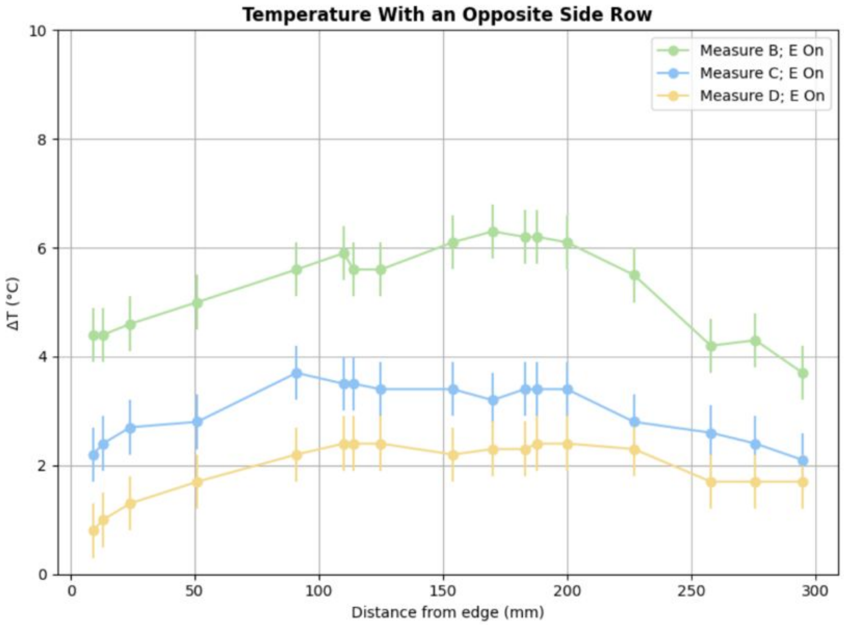
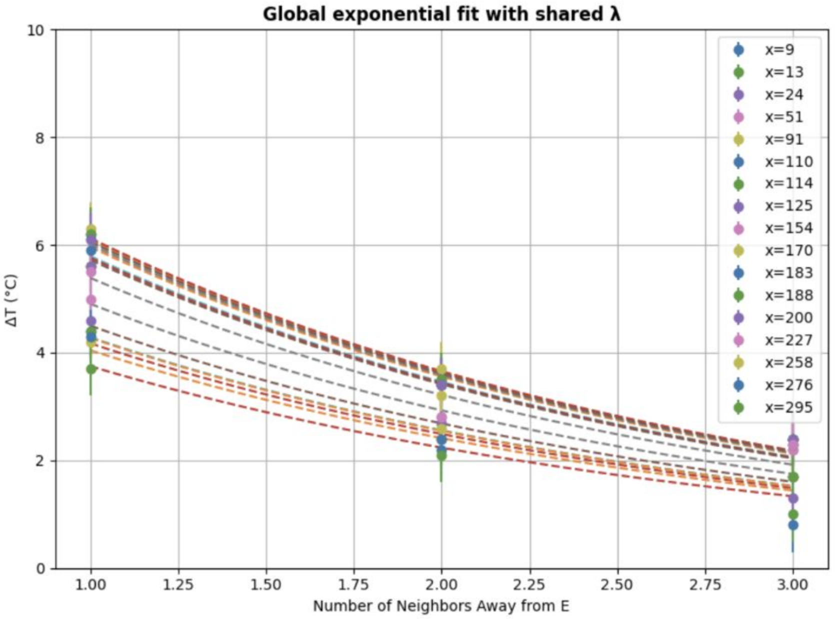




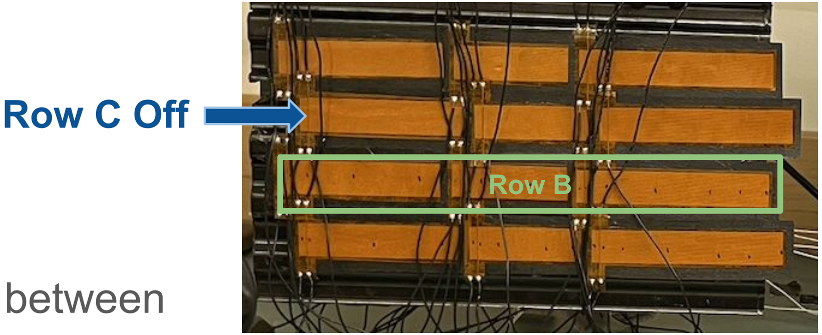
Opposite Side Neighbors

- Measurements were taken across row B, C then D with Row E On
- The global fit yielded a decay length of λ = 1.938 ± 0.037 neighbor units, which as expected is greater than that of the same-side neighbor effect



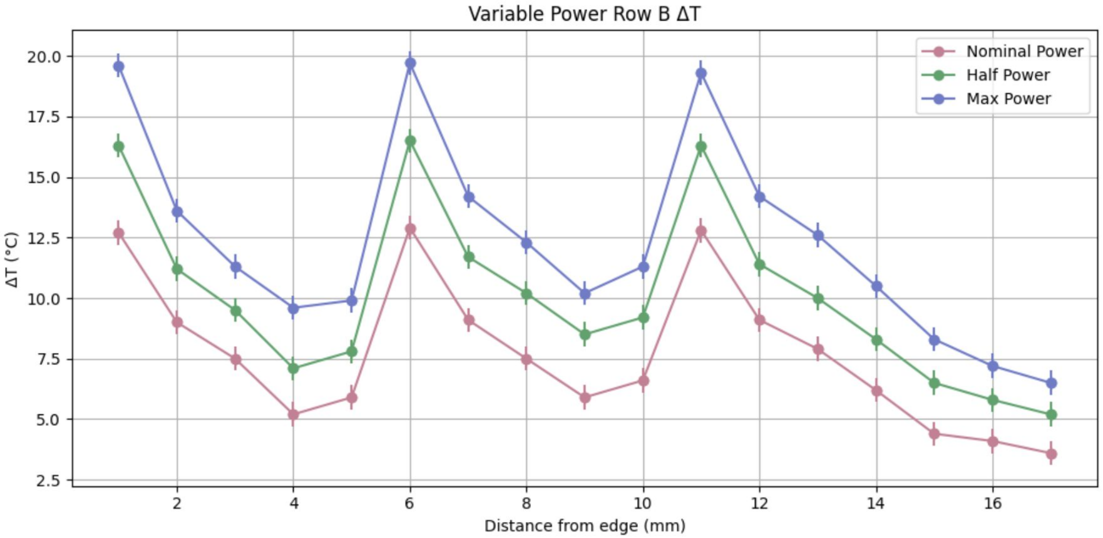


Single Row Power Densities



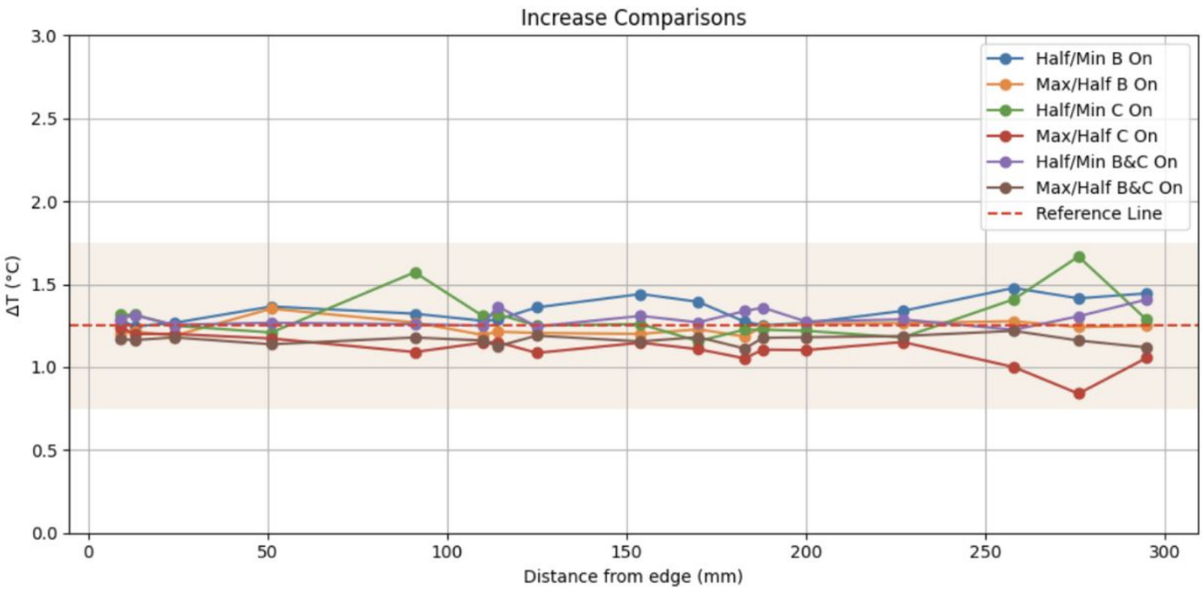
Measurements were taken across **Row B**

- Measured at nominal, maximum, and halfway between
- Difference in temperature **seems linear** with increasing power



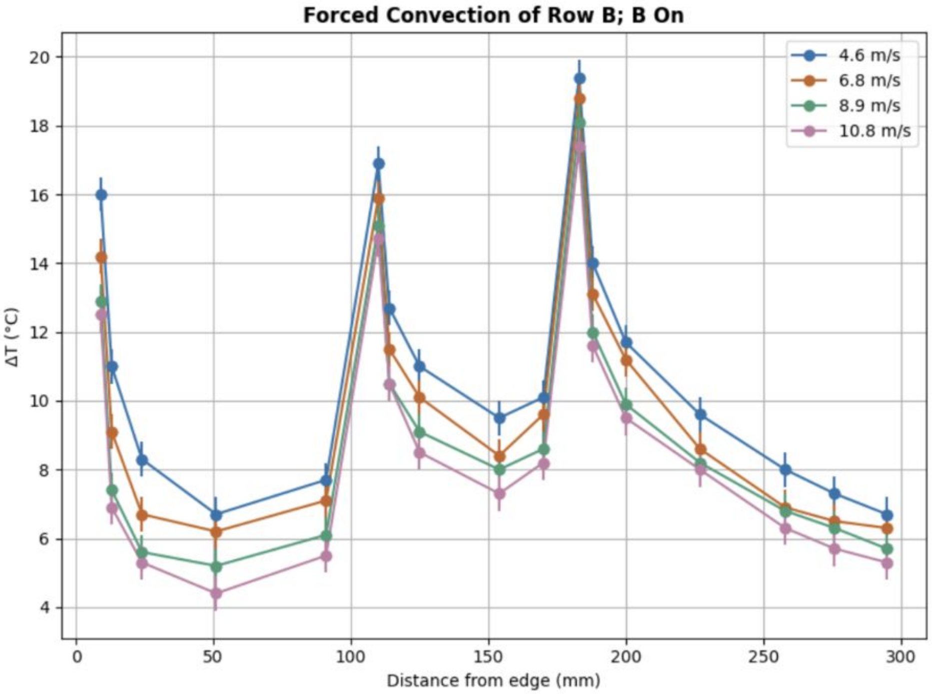
Multi Row Power Analysis

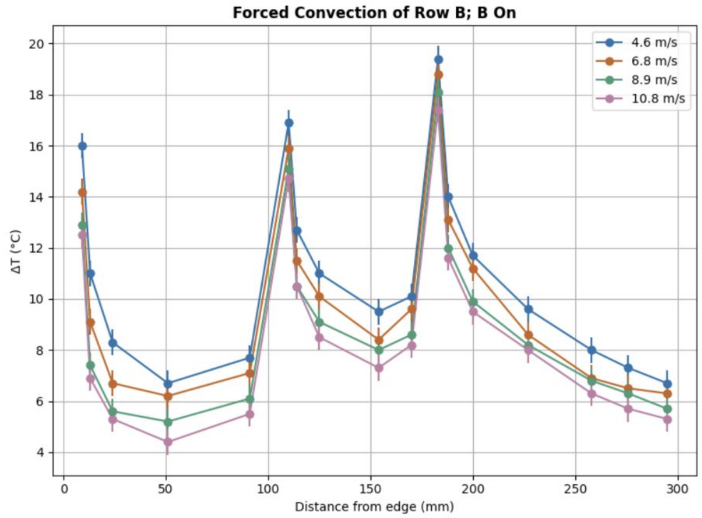
- Analysis of temperature differences between power levels revealed an increase of roughly 1.25 degrees per 0.35 W
- All measurements fell well within the error of 0.5 degrees

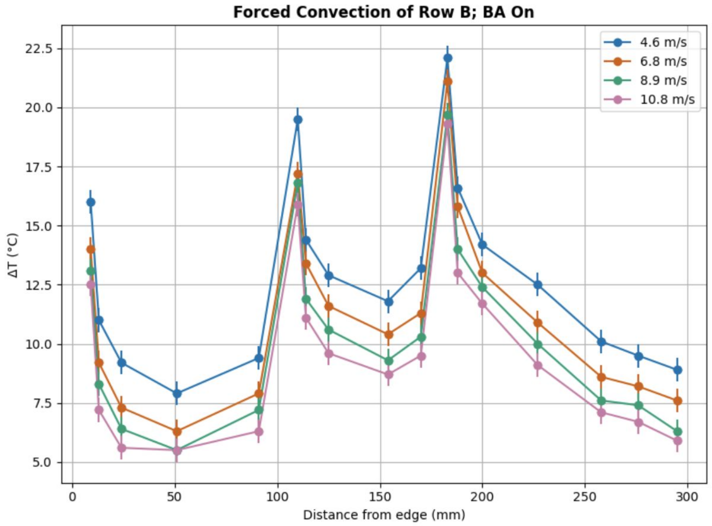


Forced Convection Studies

- Four discrete velocities were investigated: 4.6, 6.8, 8.9, and 10.8 m/s
- Temperature measurements were recorded after achieving steady state, typically 2-3 minutes after flow initiation
- With row B operating at maximum power, increasing air velocity reduced peak temperatures from 42.1°C to 38.6°C




Forced Convection of Row B; B On
ΔT (°C)
Distance from edge (mm)
4.6 m/s
6.8 m/s
8.9 m/s
10.8 m/s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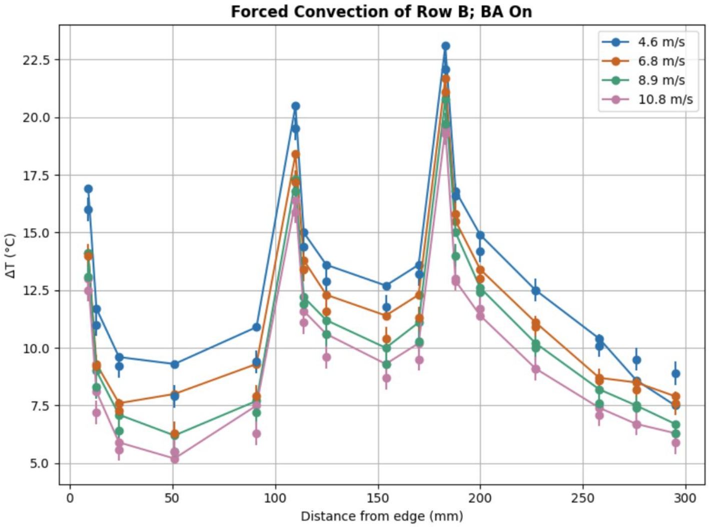
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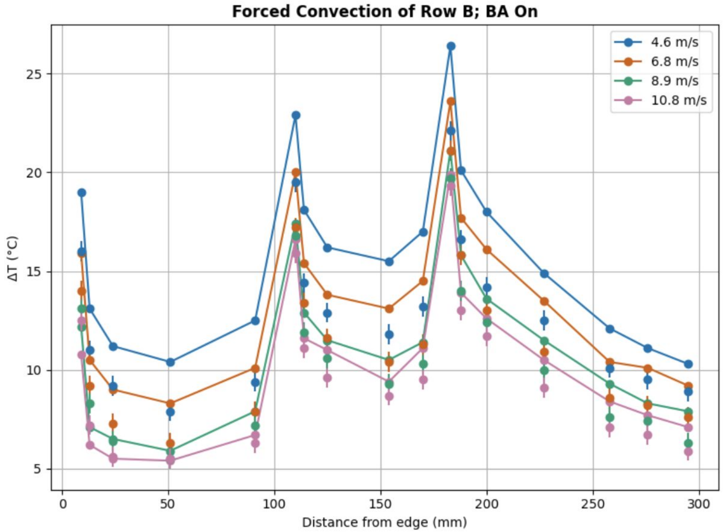
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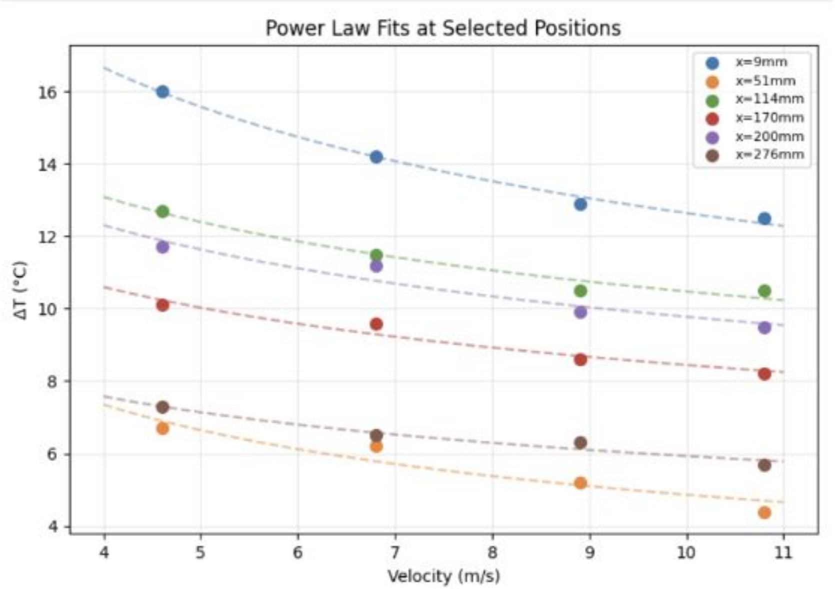
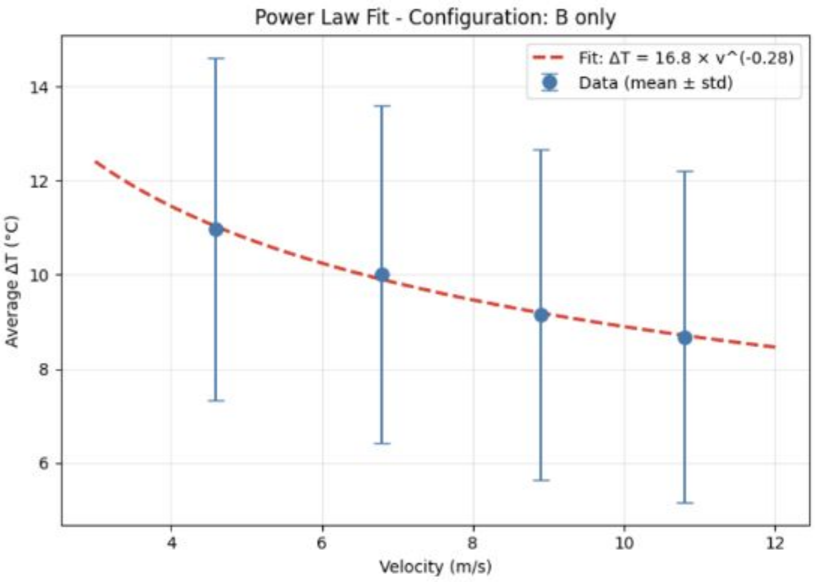
Forced Convection Studies

$$\Delta T = A \cdot V^{-n}$$

- For the baseline configuration (B only), the fitted parameters are A = 16.81 and n =
- 0.276, with an excellent fit quality (R2 = 0.9985)

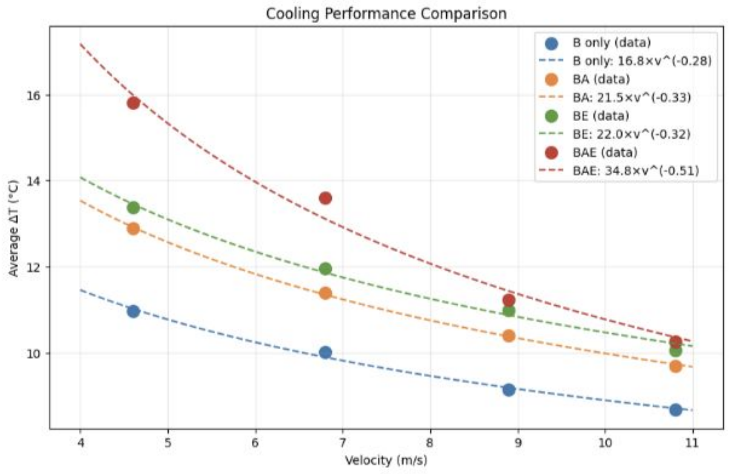


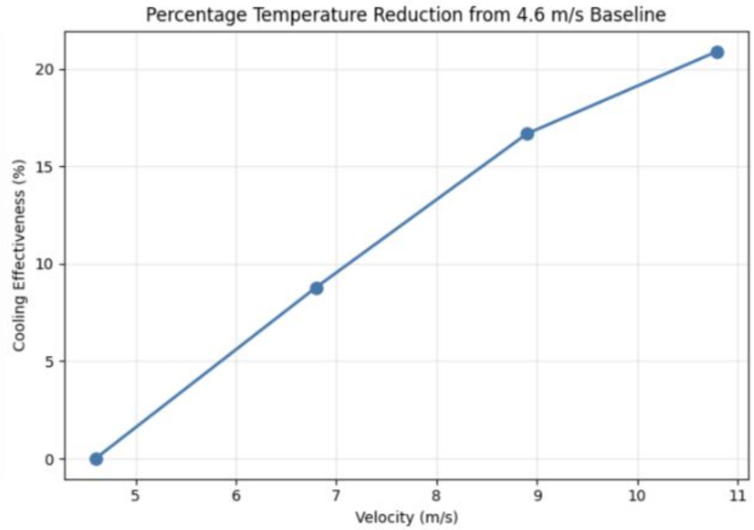


Forced Convection Studies

$$\Delta T = A \cdot V^{-n}$$

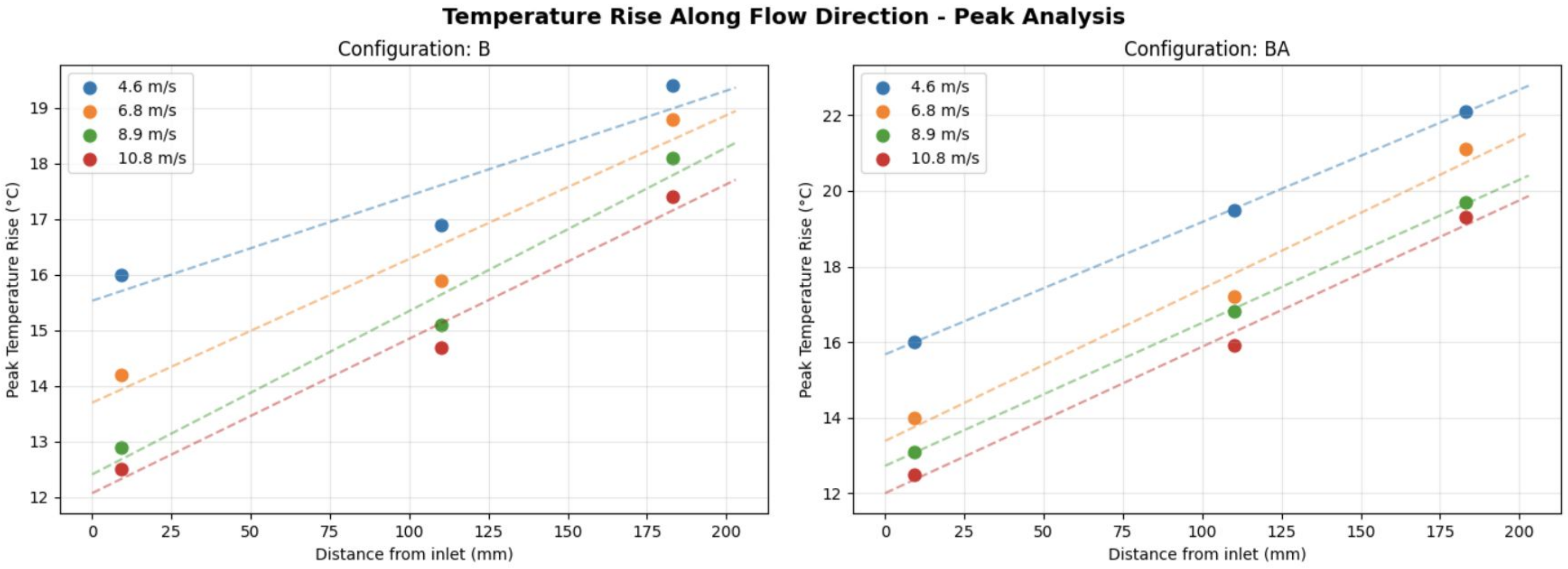
- Row BAE seems to achieve the most efficient cooling, as it has the steepest slope
- The temperature reduction rate for BAE configuration is approximately 40% steeper than for Row B alone, dropping from about 16°C at 4.6 m/s to under 10°C at 10.8 m/s.
- We also see a nearly linear relationship between cooling effectiveness (percentage temperature reduction from baseline at 4.6 m/s)





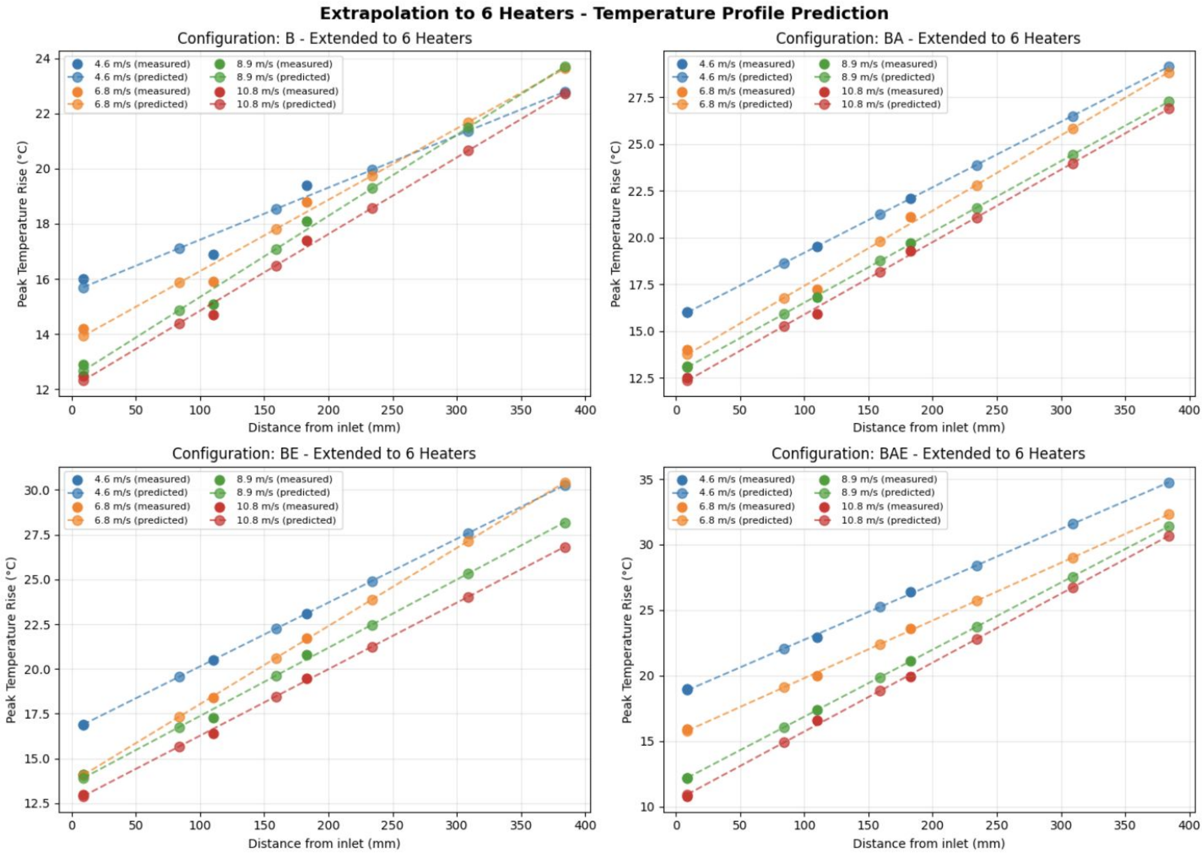
>3 Heaters in a Row

- Take LEC peak positions and create a linear fit
- Allows us to extrapolate to 4, 5, 6+ heaters in a row



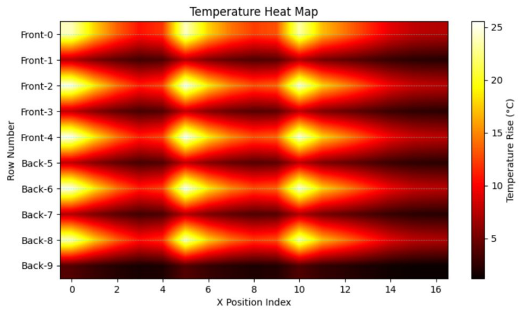
Extending the Fit

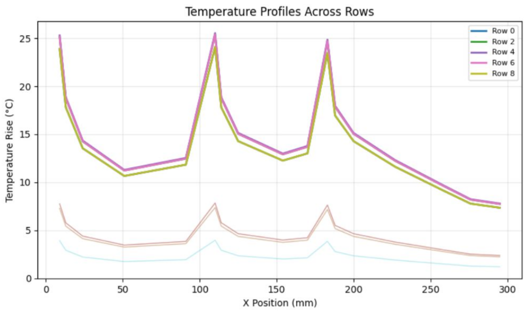
- Nothing fancy, just extended to lines for each to get a rough idea of the dT for different configs at more heaters

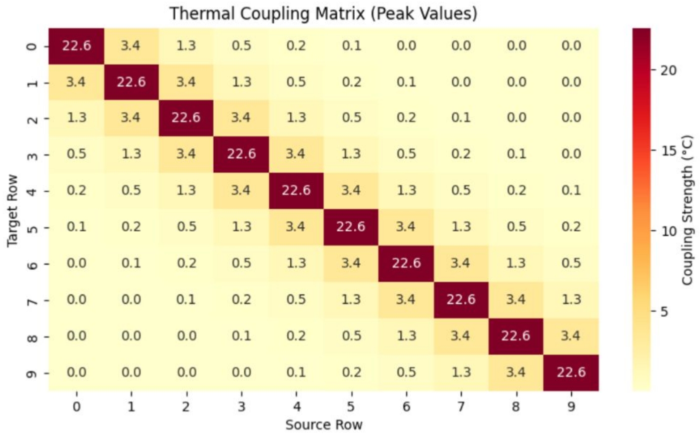


Thermal Model Predictions

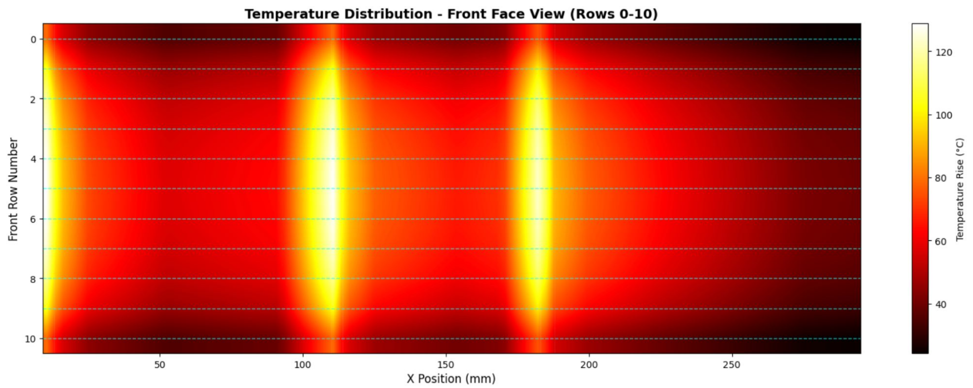
- Create a grid and solve for the temperature at each point on the grid
- Begin with the self heating profile for a row
- Consider the power density and adjust base temps
- Next consider air cooling velocity and make adjustments to the base
- Finally, add up same side & opposite side neighbor + next to nearest neighbor

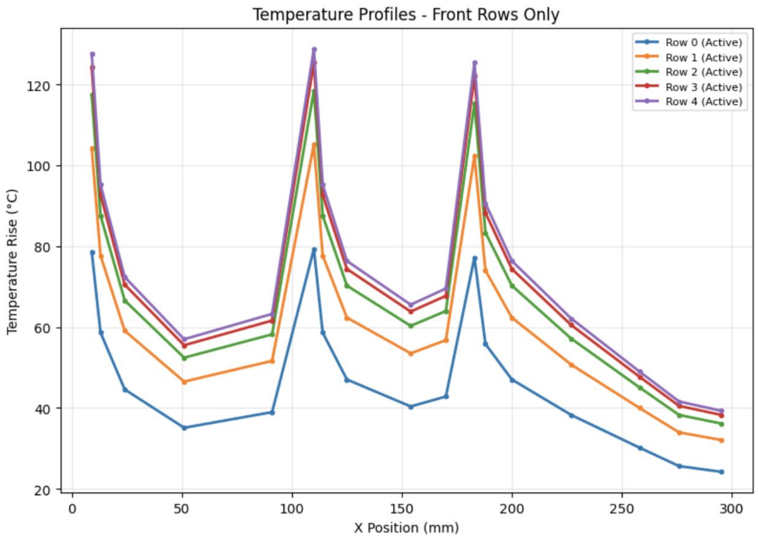






Thermal Model Predictions





- Need to add in air cooling
- But able to make calculations based on all other parameters
- Provides an experimentally grounded rough estimate for maximum LEC peak temperatures