Steam Turbine Exhaust Monitoring

Department of Mechanical Engineering, The University of Utah

PacifiCorp

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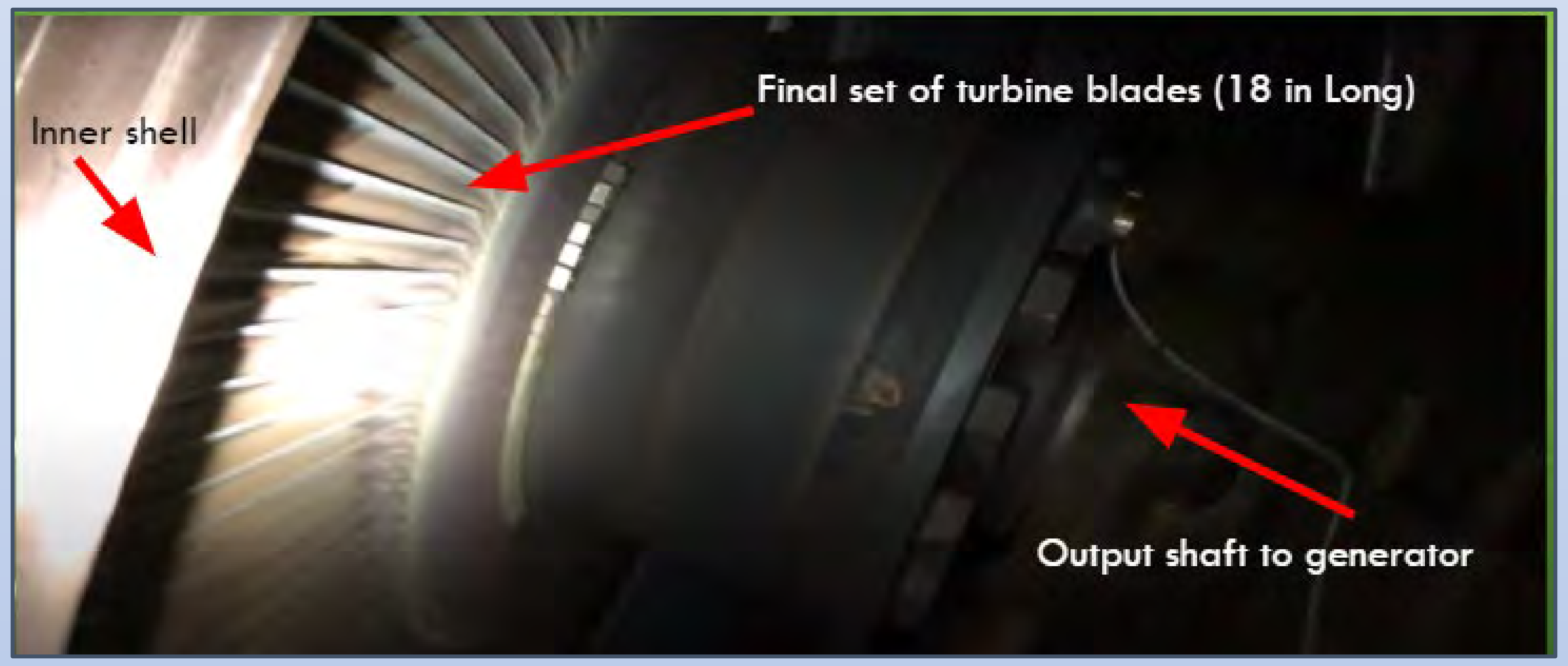
Background

Due to increases in the use of renewable energy, such as solar and wind, traditional power plants are running into new challenges. We are working with PacifiCorp to overcome challenges they are facing with one of their steam turbines. The power output of wind and solar is variable, as it depends on factors like wind speed or light intensity. With varying power coming from renewable energy sources, the steam turbine must also vary its power output to meet grid demand. Traditional steam turbines from the 1950s, like the one investigated in this project, are meant to modulate output power near 100% capacity. However, when power output from renewables is highest, the turbine must ramp down to around 20% capacity.

Operating at the low extreme of the steam turbine's capacity is causing undesirable flow conditions, particularly near the last set of the turbine blades. It's been observed that ramping down capacity causes steam flow to reverse and travel back into the turbine blades. This causes vibrations in the turbine blades that lead to costly fractures and wear and tear.



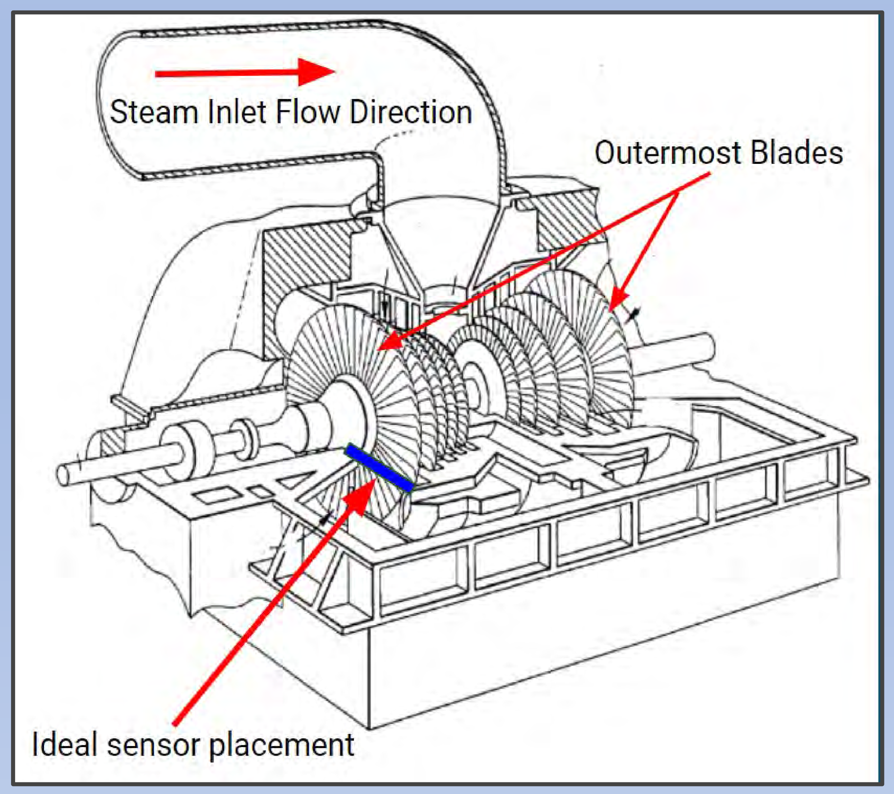
View of outer turbine blades within Pacificorp steam turbine

Project Scope

- Create a sensor array to monitor the flow conditions at the turbine outlet
- Primary concern is reverse flow, device must measure flow velocity in multiple directions
- Ability to determine when undesirable flow arises in real-time, which will allow operators to quickly change turbine operation to prevent damage

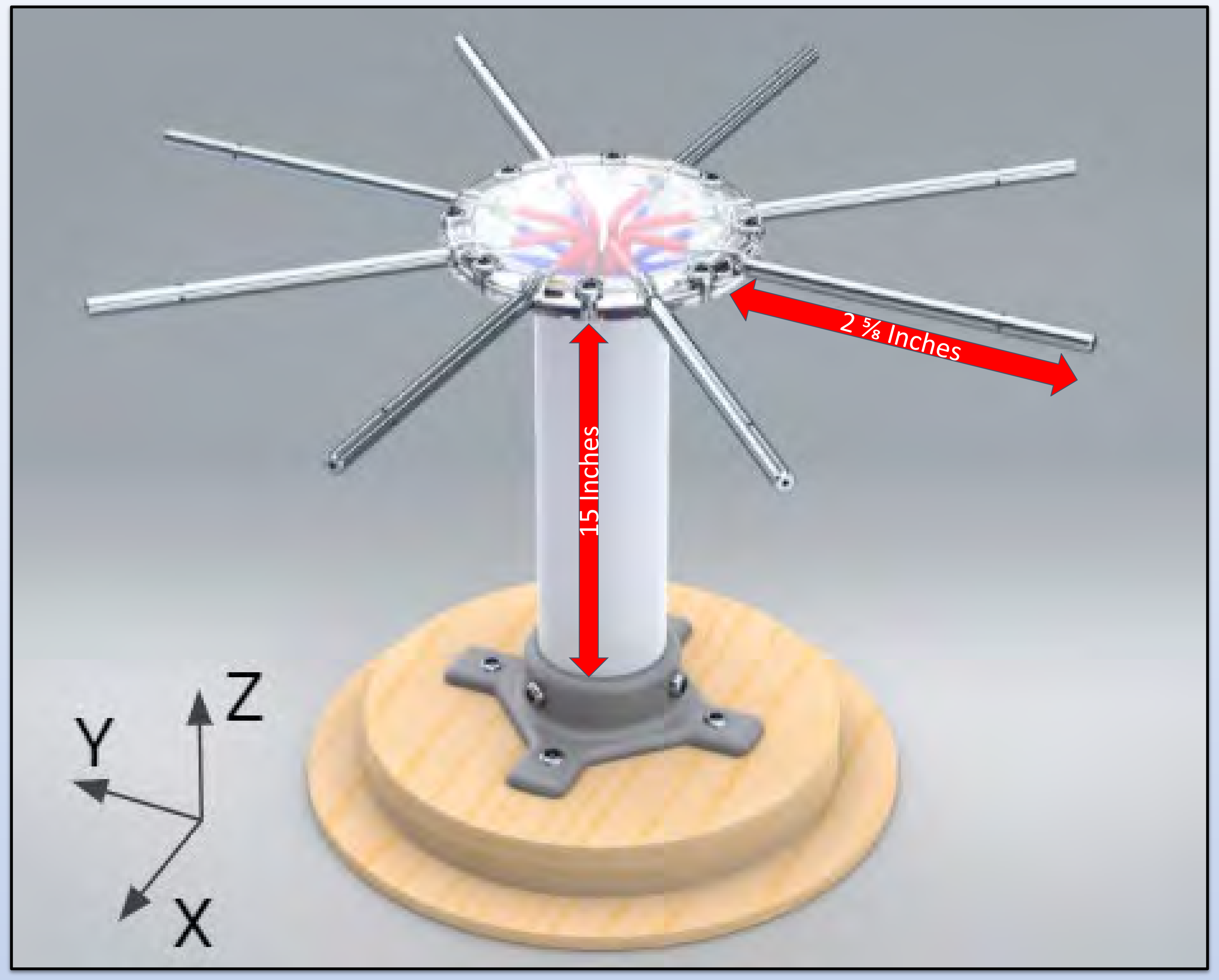
Objective	Metric	Design Solution
Measurement Requirement	Accurately characterize flow direction	Omnidirectional Pitot Tube Probe
Size Constraint	Fit within turbine opening (<3ft in dia.)	Probe diameter of 1 ft
Temperature Constraints	Withstand temps. up to 200°F	Theoretically operational up to 150°F
Project Cost	Under $5,600	Total cost: $1,278.56

Project objectives and solutions



Internal view of turbine with ideal sensor placement

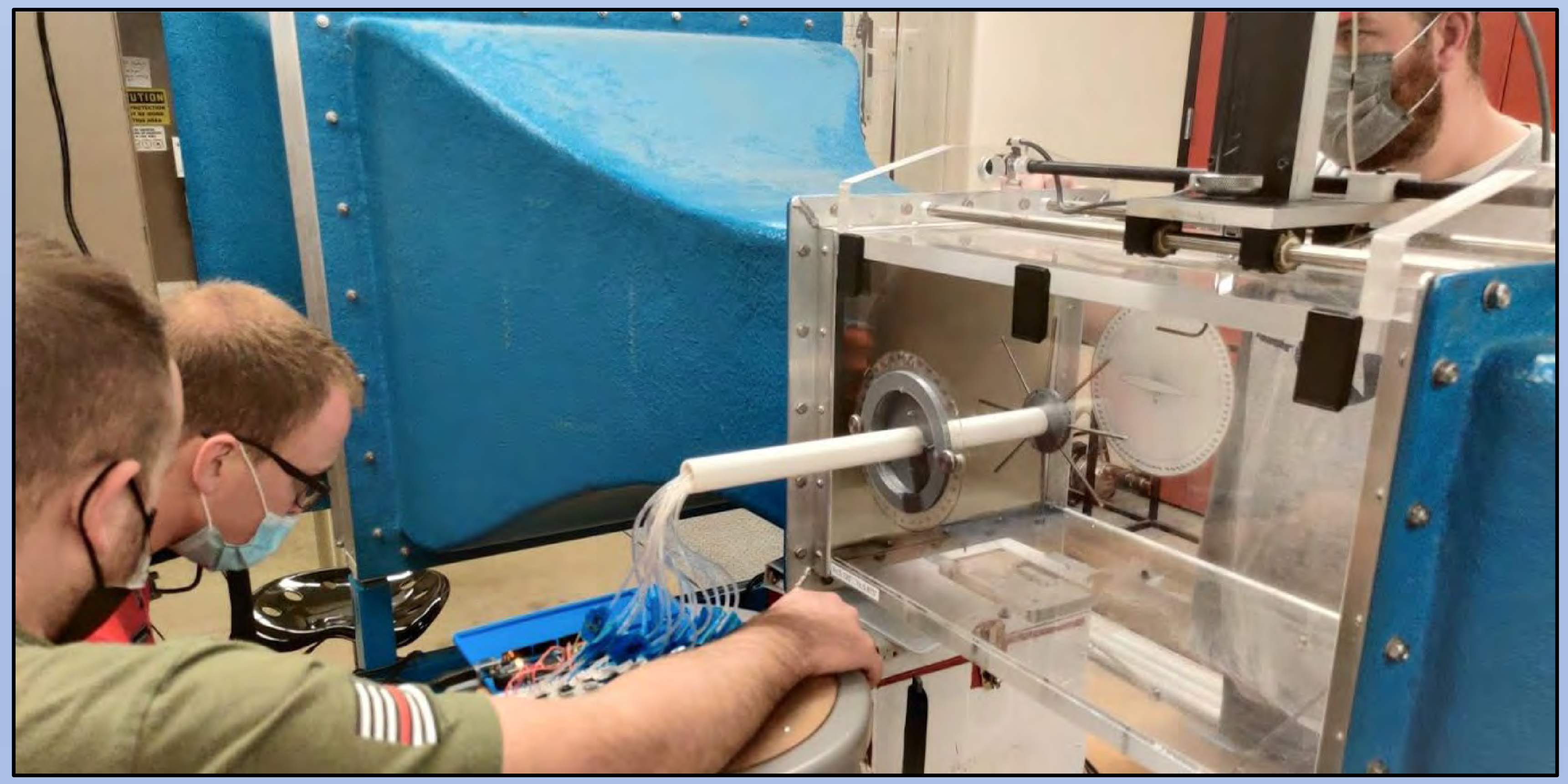
Design



Final prototype rendering

- 8 pitot tubes arranged 45 degrees apart from each other
- Velocity can be measured in several directions simultaneously
- The center tube can rotate in the X-Y plane
- The center tube may be extended and retracted in the Z direction

Test Methods

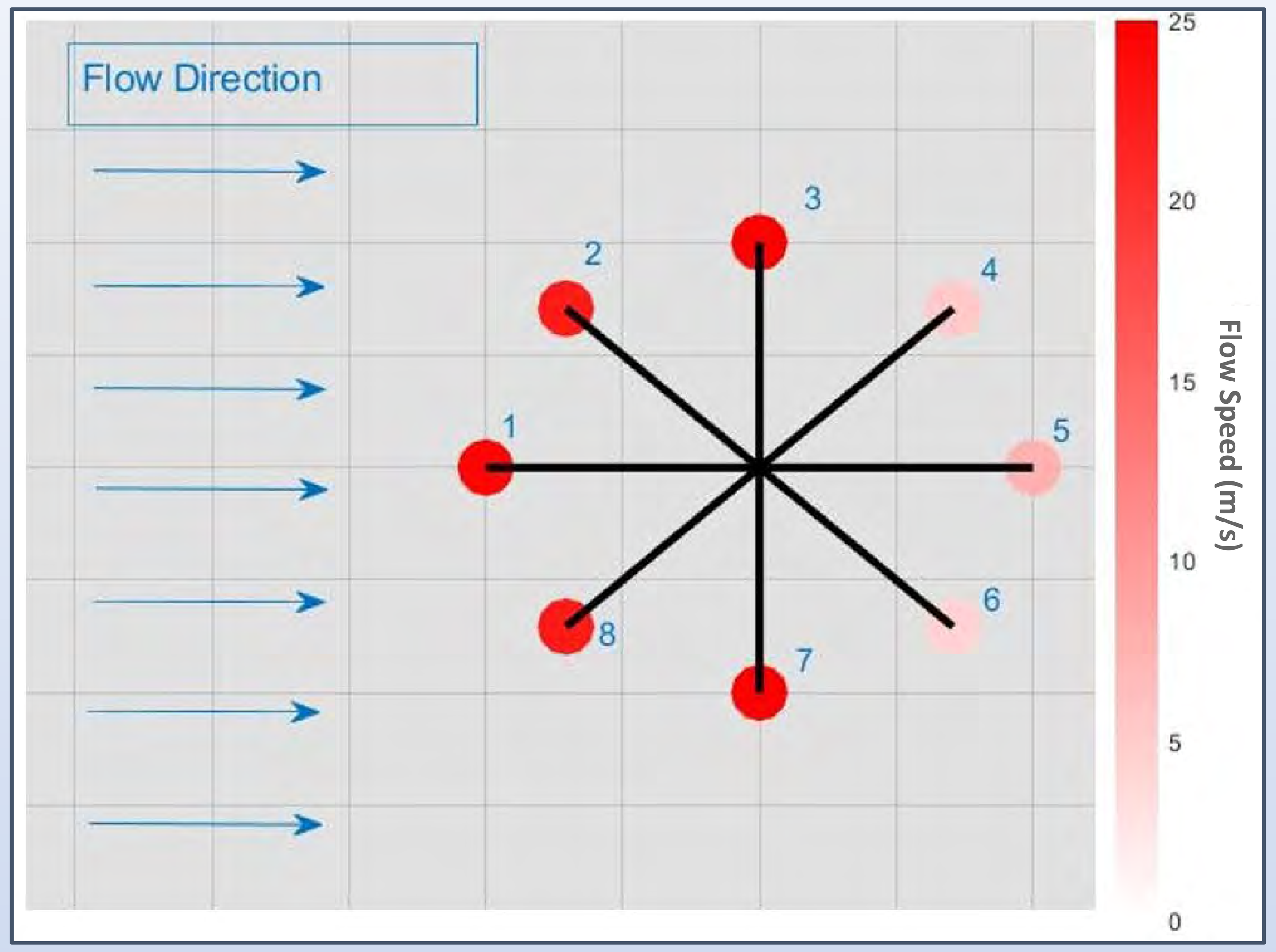


Testing of prototype within wind tunnel test section

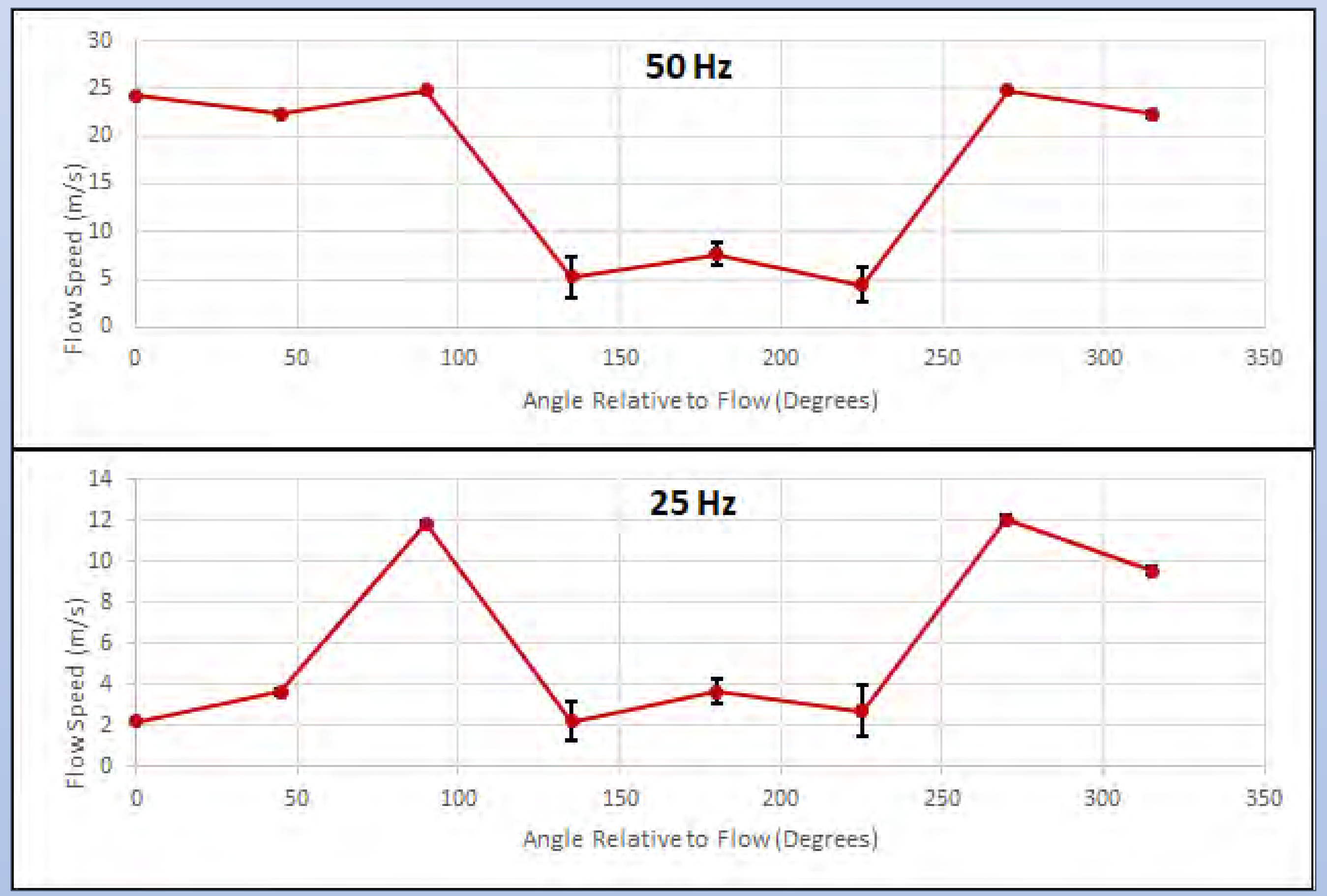
- Used wind tunnel in U of U lab
- Laminar flow in test section
- Verified prototype hardware accuracy with lab's hardware
- Use static and dynamic pressure measurements in the Bernoulli equation to find velocity

$$V = \sqrt{\frac{2\Delta P}{\rho}}$$

Results



Pitot tube speed profile at 50Hz wind tunnel fan speed. Speed measurement for pitot tube at each location indicated by color bar



Top: Flow speed at 50 Hz wind tunnel speed w/ st. dev. bars, Bottom: Flow speed at 25 Hz wind tunnel speed w/ st. dev. bars

- 5 readings per second, measurements taken for 10 seconds
- Measurement readings relatively constant at steady state
- Measurement uncertainty increases in tubes facing away from flow
- Small speed increase in pitot tube 5 relative to adjacent pitot tubes
- Device can theoretically measure backflow

Conclusion

Due to project logistics, we are not able to create a final design that could be installed in the steam turbine. Our prototypes and testing have served as a proof of concept. To complete the project, we will:

- Finalize prototype testing
- Complete a final design with a more durable material that could be installed in Pacificorp's turbine