Performance Enhancement of a Modular Low-Speed Wind Tunnel

Dylan Freeman, Ahmed Aboelezz
Department of Mechanical Engineering, University of Maine

Abstract

Characterizing airflow performance is critical for optimizing the design of low-speed wind tunnels, which are essential for generating controlled, uniform airflow required for aerodynamic research. The wind tunnel studied in this project is an 8-ft-long, fully modular, blower-configuration tunnel with a 12.5 × 12.5 in. test section that was designed and manufactured on the University of Maine campus. Its modularity allows each component, including the settling chamber, convergence nozzle, and test section, to be replaced for various testing scenarios. Initially, preliminary characterization of the wind tunnel's velocity profile was performed using a seven-hole digital pitot tube mounted on a linear xy-traverse. Additionally, a differential pressure manometer measured the static pressure rise across the fans. Initial results showed a variation in the velocity profile of 0.7% when compared to the mean axial velocity, which is acceptable for aerodynamic research. However, the maximum measured velocity was only 10 m/s, well below the 20–50 m/s expected for low-speed wind tunnels. To address this limitation, higher-performance fans were sized using system curves generated from the original fans' characterization data to meet the design requirement of 20 m/s. Achieving this higher velocity expands the range of obtainable Reynolds numbers, allowing for more versatile aerodynamic testing of airfoils, micro-UAVs, and other applications that require high-quality airflow within the test section. Ultimately, this study compares the experimental results of the new fan configurations against their predicted performance, which was extrapolated from the original setup.

Wind Tunnel Overview

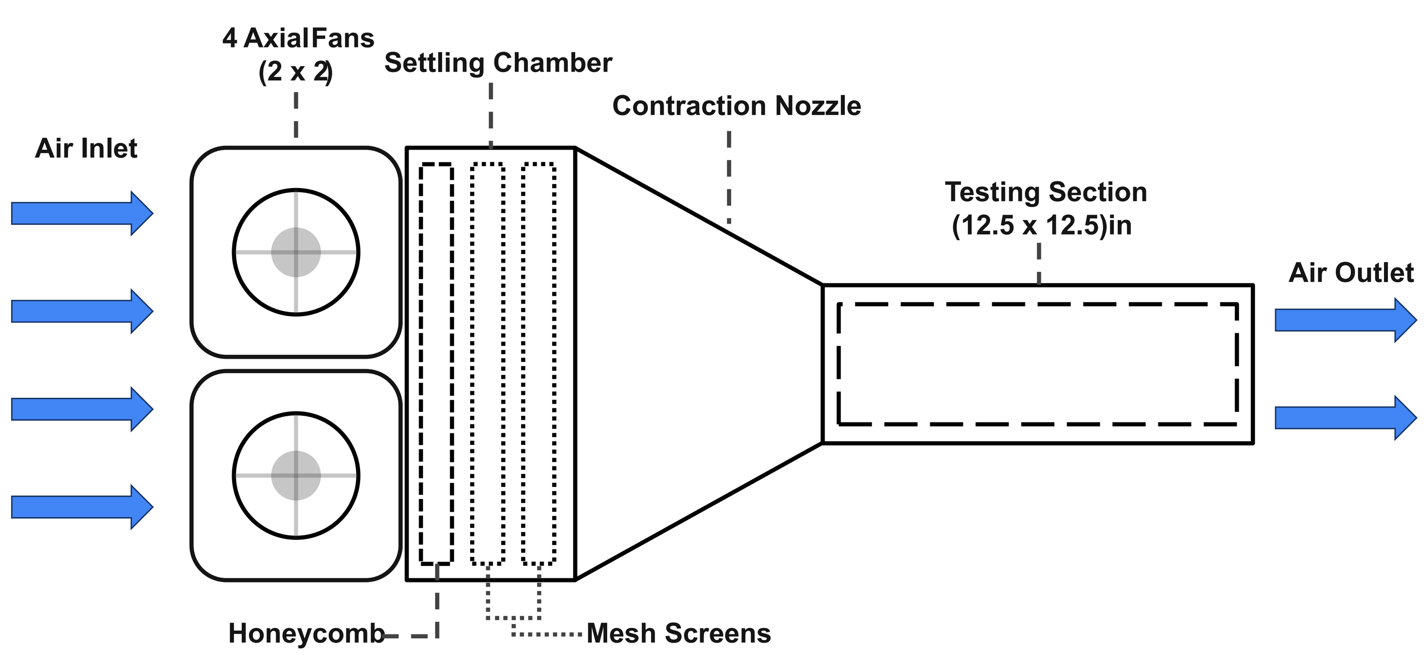


Figure 1. Modular Wind Tunnel Top View Schematic

Figure 2. Isometric View of Original Configuration

Characterization Methods

Characterization Method

1. Measure velocity profile using an xy linear traverse and seven-hole digital pitot tube.
2. Measure static pressure rise across the fans using a digital manometer.
3. Generate velocity contours and fan system curves to inform sizing analysis.
4. Use characterization plots to generate system curves for sizing the new configuration.

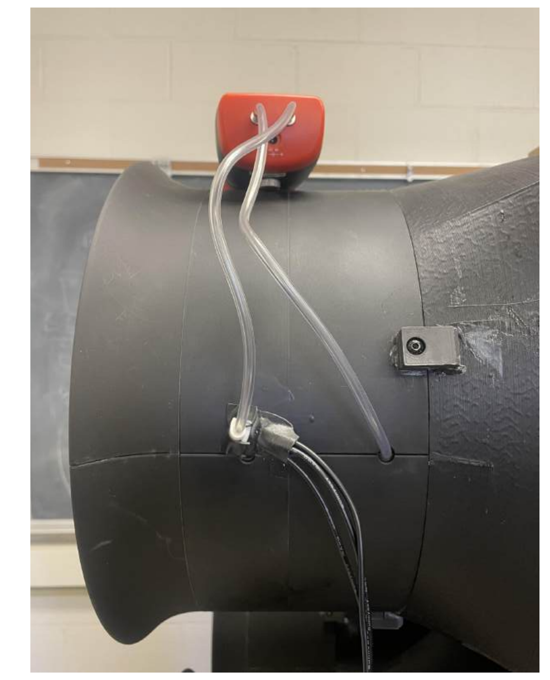


Figure 3. Differential Monometer Installed on Fan (shown on right)

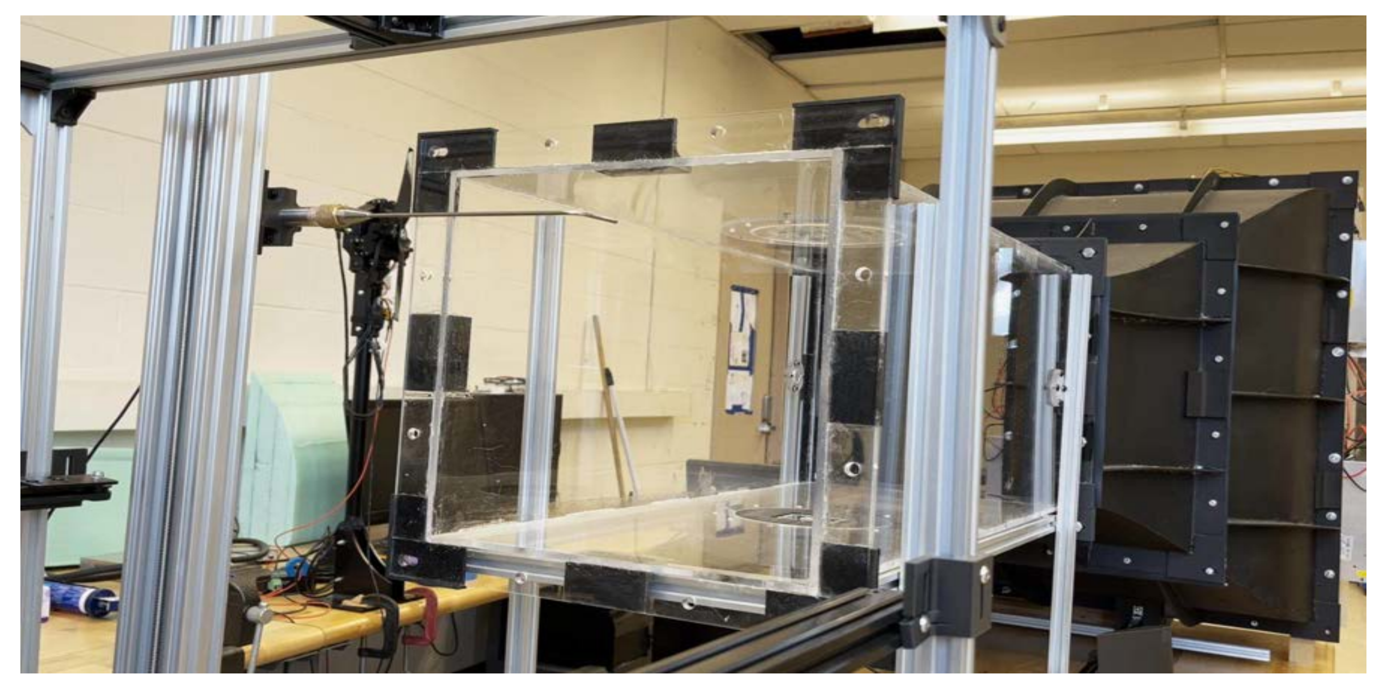
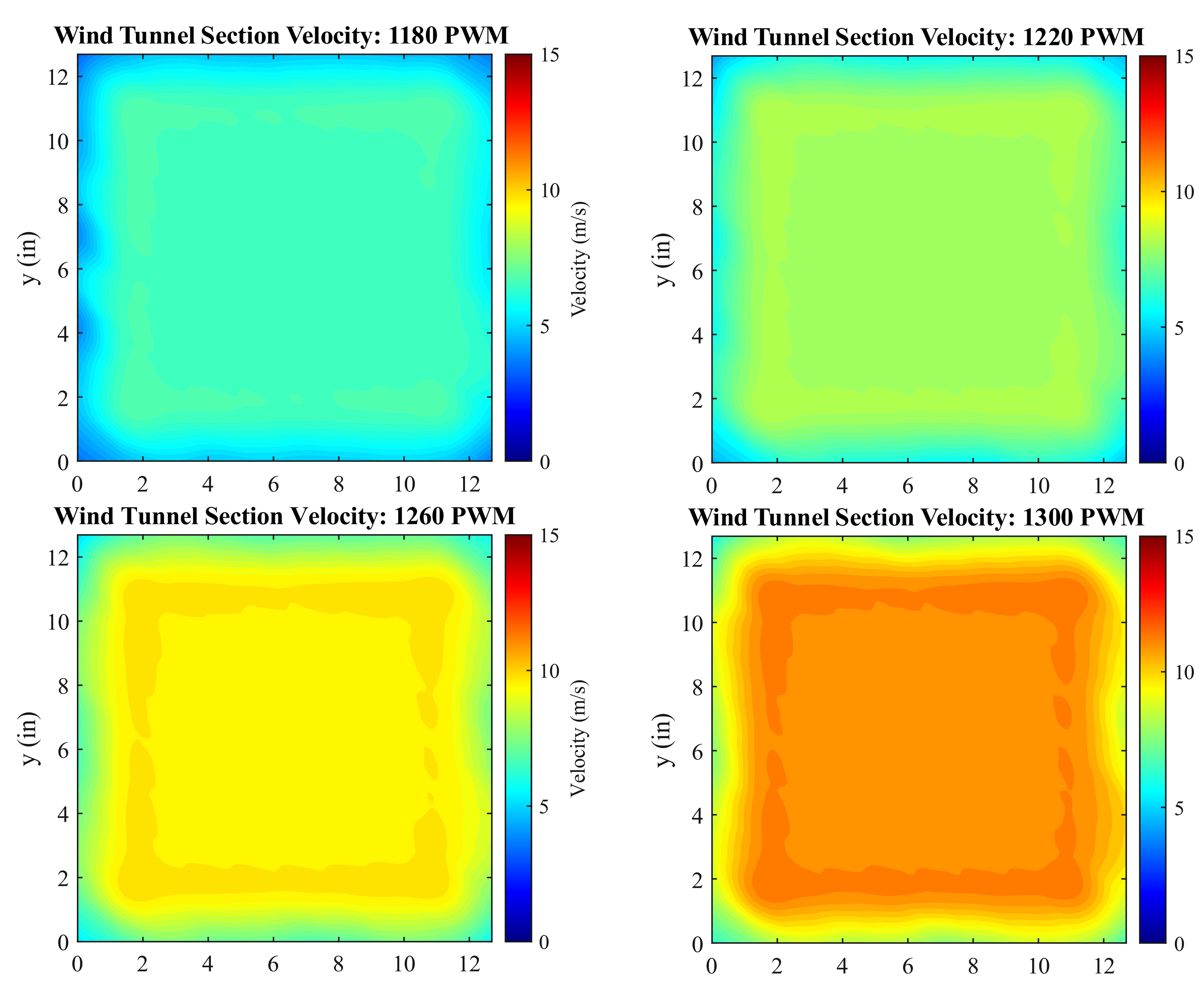
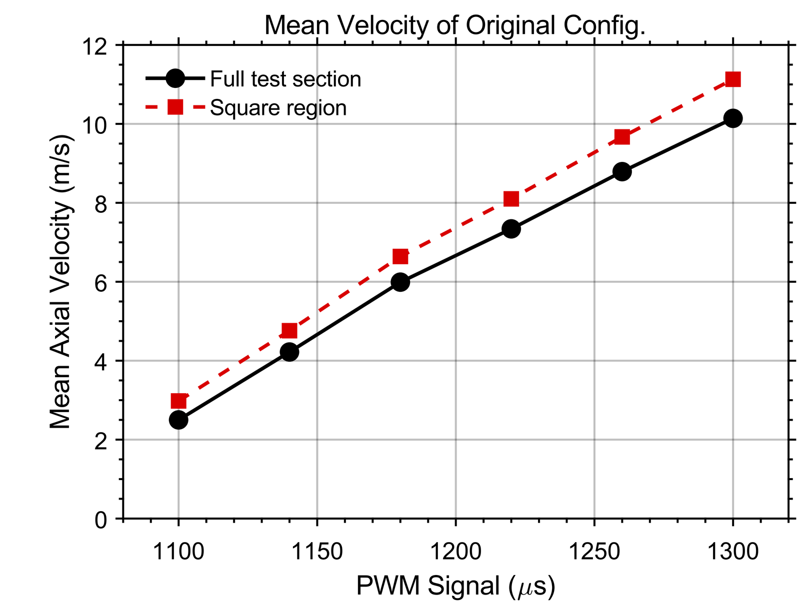


Figure 4. Pitot Tube Measurements

Characterization Results

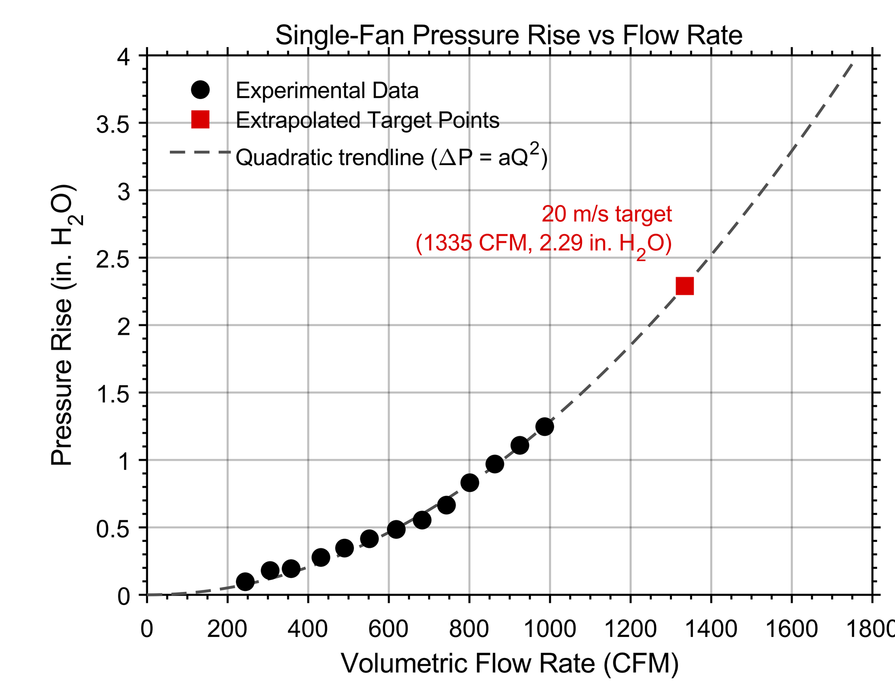




Discussion

Initial characterization showed an acceptable turbulence intensity of less than 1% when excluding the wall boundary layers. However, the maximum mean velocity was only 10 m/s. To reach the 20 m/s design target, a quadratic trendline was fit to the measured fan data and extrapolated to find the required pressure rise, which was then used to select new fans whose performance curves met the operating point.

Sizing of the New Fans



Configuration	Flow Rate (CFM)	Pressure Rise (in. H_2O)
Original fans	986.9	1.25
New fans (predicted)	1335	2.29
New fans (installed)	5395	1.90

New Fan Frame

New Frame Design

A new frame was designed to accommodate the larger and heavier fans. It was fabricated from 18 mm Baltic birch plywood on a CNC router, then assembled alongside the fans.

Figure 5. New Fans Mounted in the Custom-Built Baltic Birch Frame

Future Work

- Characterize the new fan configuration and compare measured performance against the system-sizing predictions.
- Develop a control interface that sets VFD frequency from a user-specified target velocity.
- Perform airfoil experiments (e.g., NACA 0012), apply wind tunnel corrections for wake and solid blockage, and validate lift and drag against published data.

Acknowledgements

I would like to thank and acknowledge the Maine Space Grant Consortium for their support of this project, as well as Noah Roos, Ahmed Kandil, Ahmed Aboelezz for their assistance throughout.