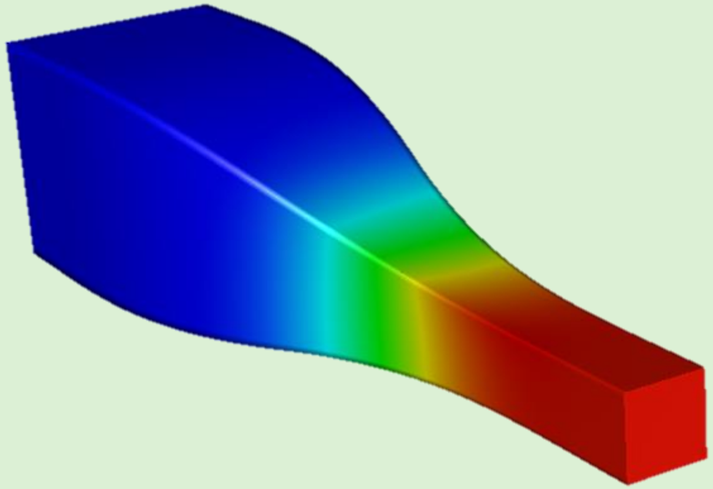
NOZZLE DESIGN FOR A SMALL, LOW-SPEED, CLOSED-RETURN WIND TUNNEL



Jeremy Martin

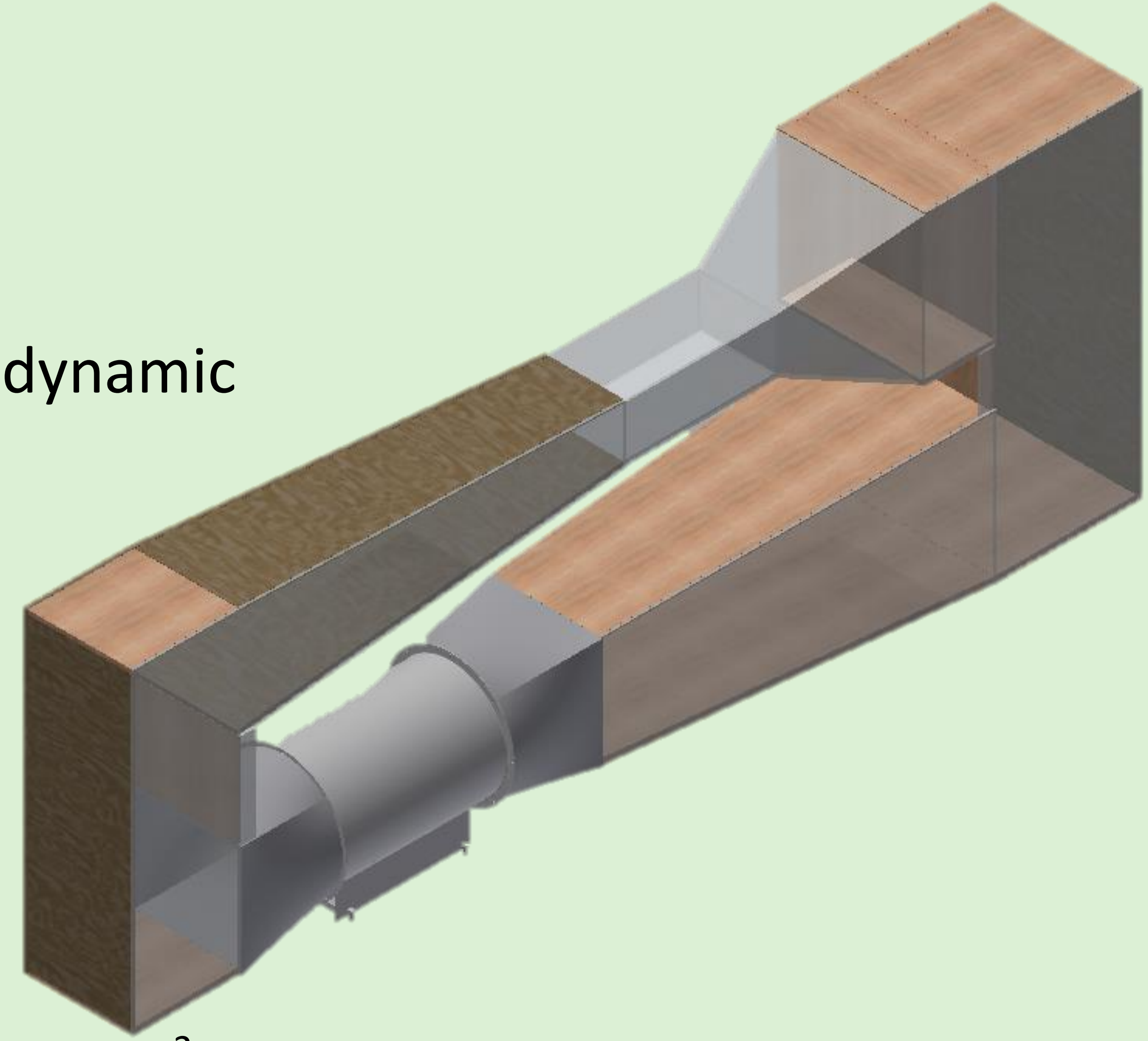
Dr. Kurt Aikens

Houghton College

Description

- What is a wind tunnel?

- Used to determine the aerodynamic properties of an object
  - Forces: Lift, Drag, Side force
  - Moments: x, y, z



Applications of wind tunnels

https://www.pinterest.com/pin/445997169318712681/

https://taskandpurpose.com/wingboarding-extreme-sport-future-future-arrived/

https://gizmodo.com/general-motors-wind-tunnels-arent-only-used-to-test-the-1517349997

http://www.ccea.zju.edu.cn/cceaenglish/2016/0324/c6034a426975/page.htm

Goals

- Minimize energy loss across nozzle

- Flow uniformity in test section
  - Avoid turbulence

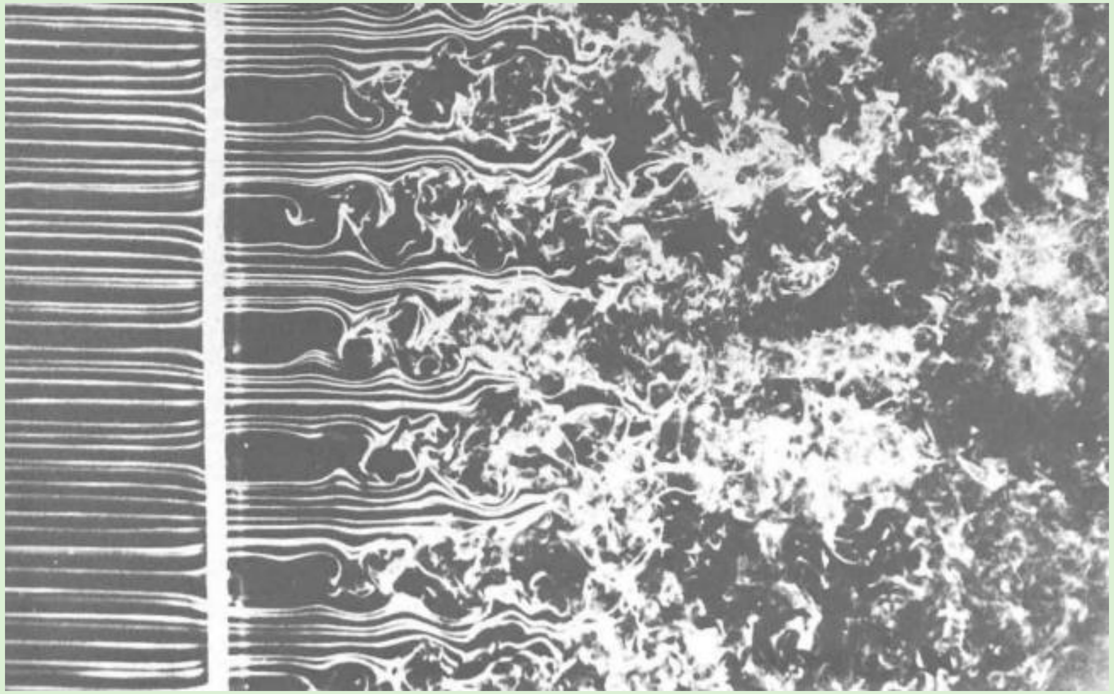


Image taken from Van Dyke

Governing Equations

- Navier-Stokes equations
  - Conservation of Mass (1 eq.)
  - Newton's Second Law (3 eqs.)
  - Conservation of Energy (1 eq.)
  - Assume ideal gas and constant specific heats (2 eqs.)

Governing Equations

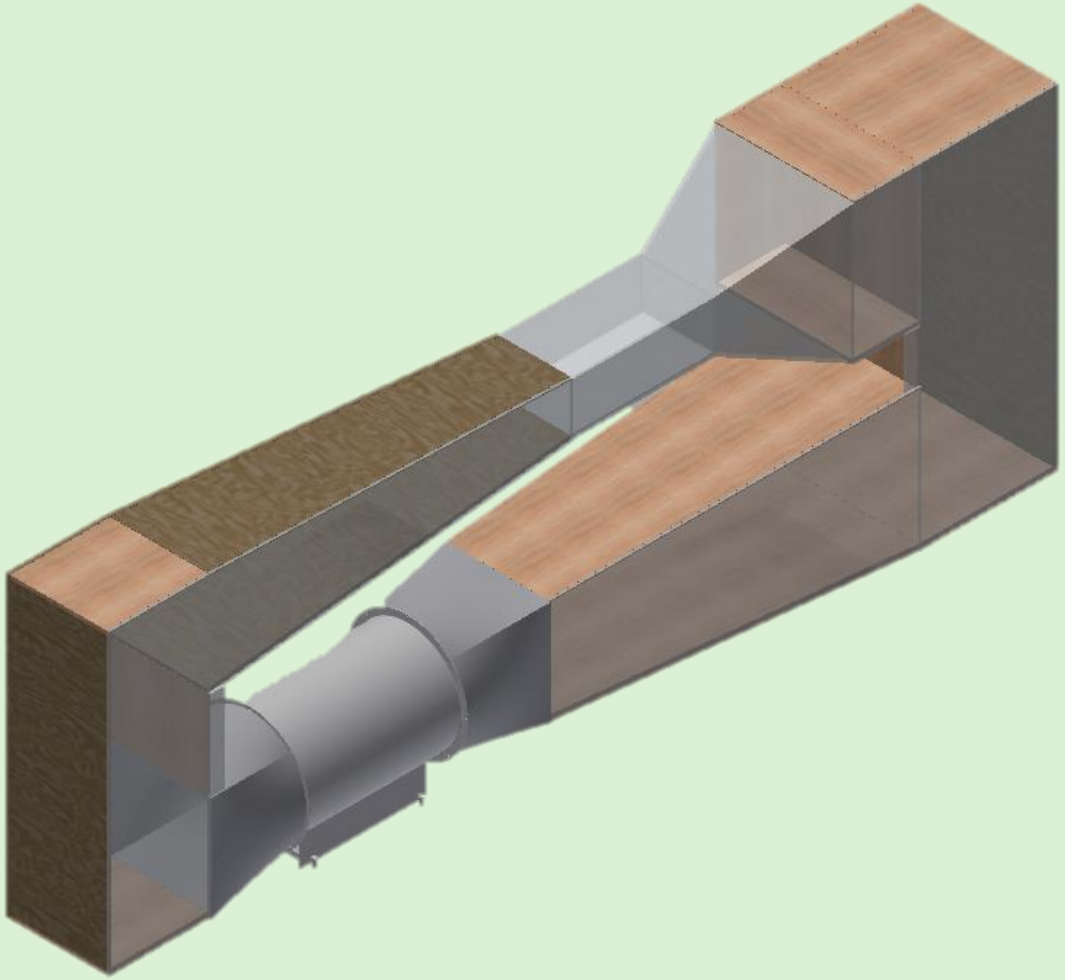
- Navier-Stokes equations
  - Conservation of Mass (1 eq.)
  - Newton's Second Law (3 eqs.)
  - Conservation of Energy (1 eq.)
  - Assume ideal gas and constant specific heats (2 eqs.)

- Bernoulli's equation
  - $P + \frac{1}{2}\rho V^2 = P_o = \text{constant}$
    - Assumptions: inviscid, incompressible, irrotational, steady, and uniform flow, & body forces neglected

History of Project

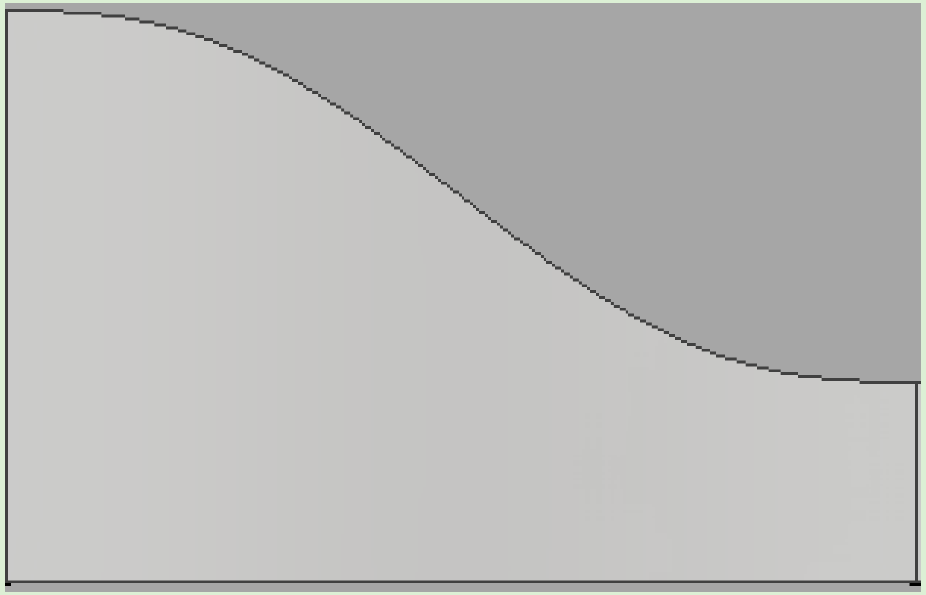
- General dimensions based on:
  - Room size
  - Commonly accepted constraints
  - Minimize energy loss

- Nozzle
  - Length: 0.55 m
  - Area-ratio: 4.0

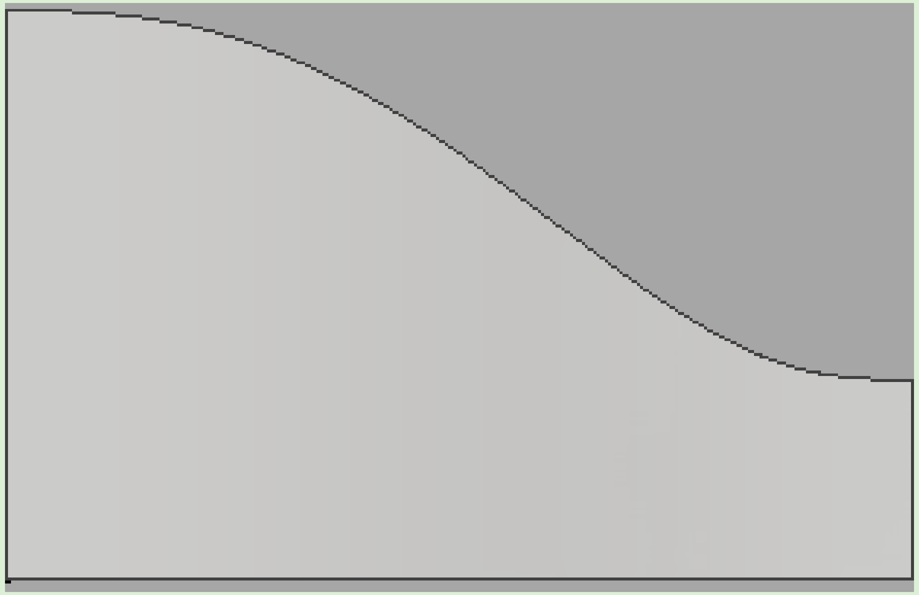


Nozzle Designs

Bell & Mehta (1988)



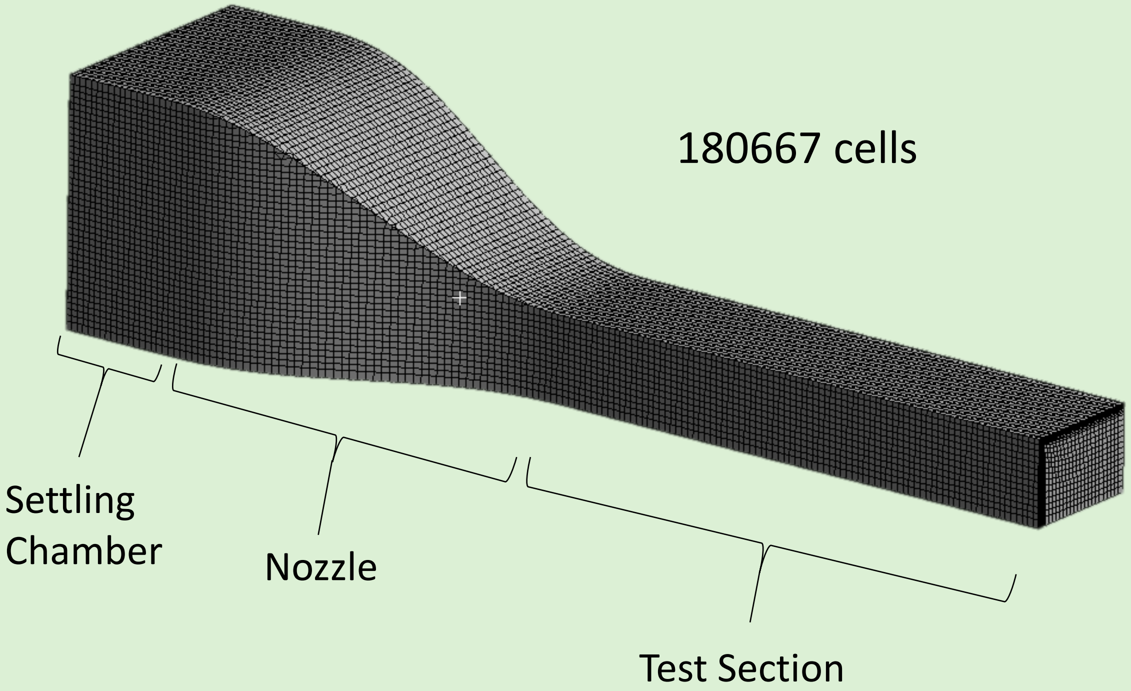
Brassard (2005)

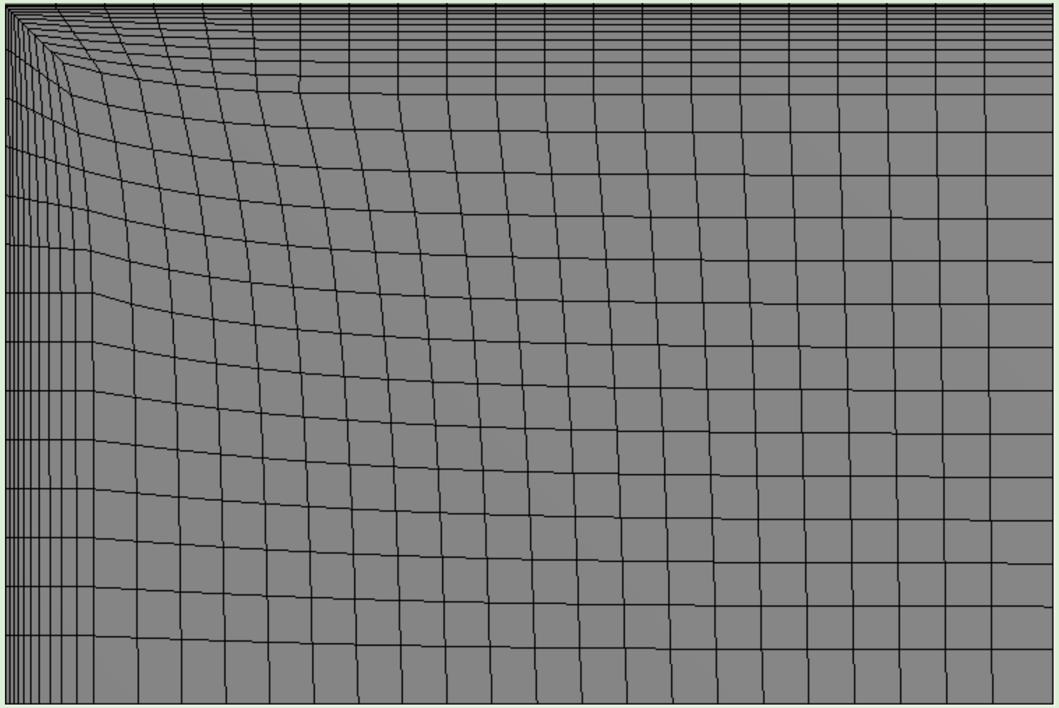


Simulations

- ANSYS Fluent
- Quarter nozzle
- Three simulations for each nozzle
  - 5 mph, 50 mph, 100mph

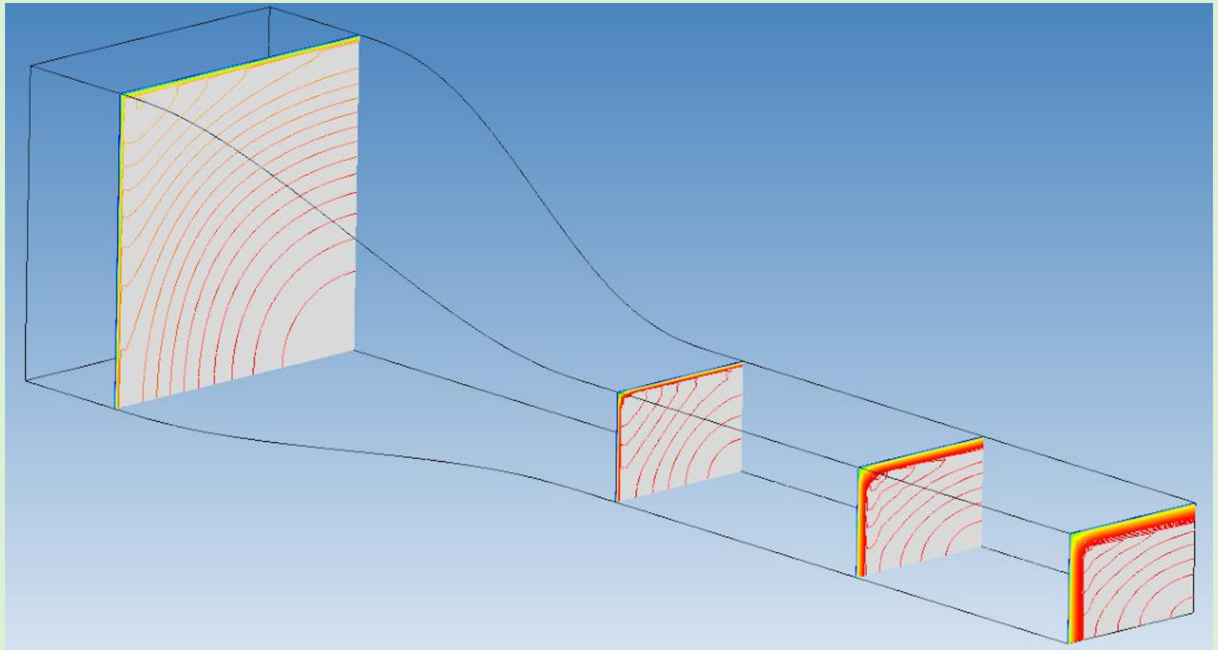
180667 cells





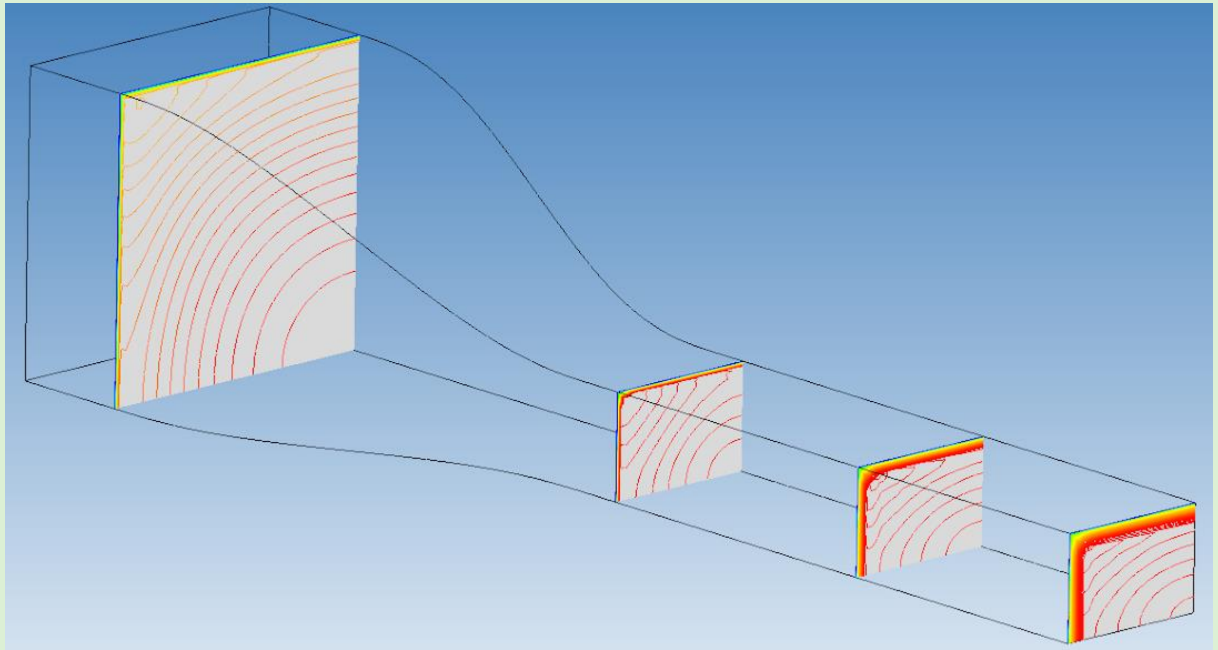
Simulation Analysis

- Stagnation pressure drop across nozzle

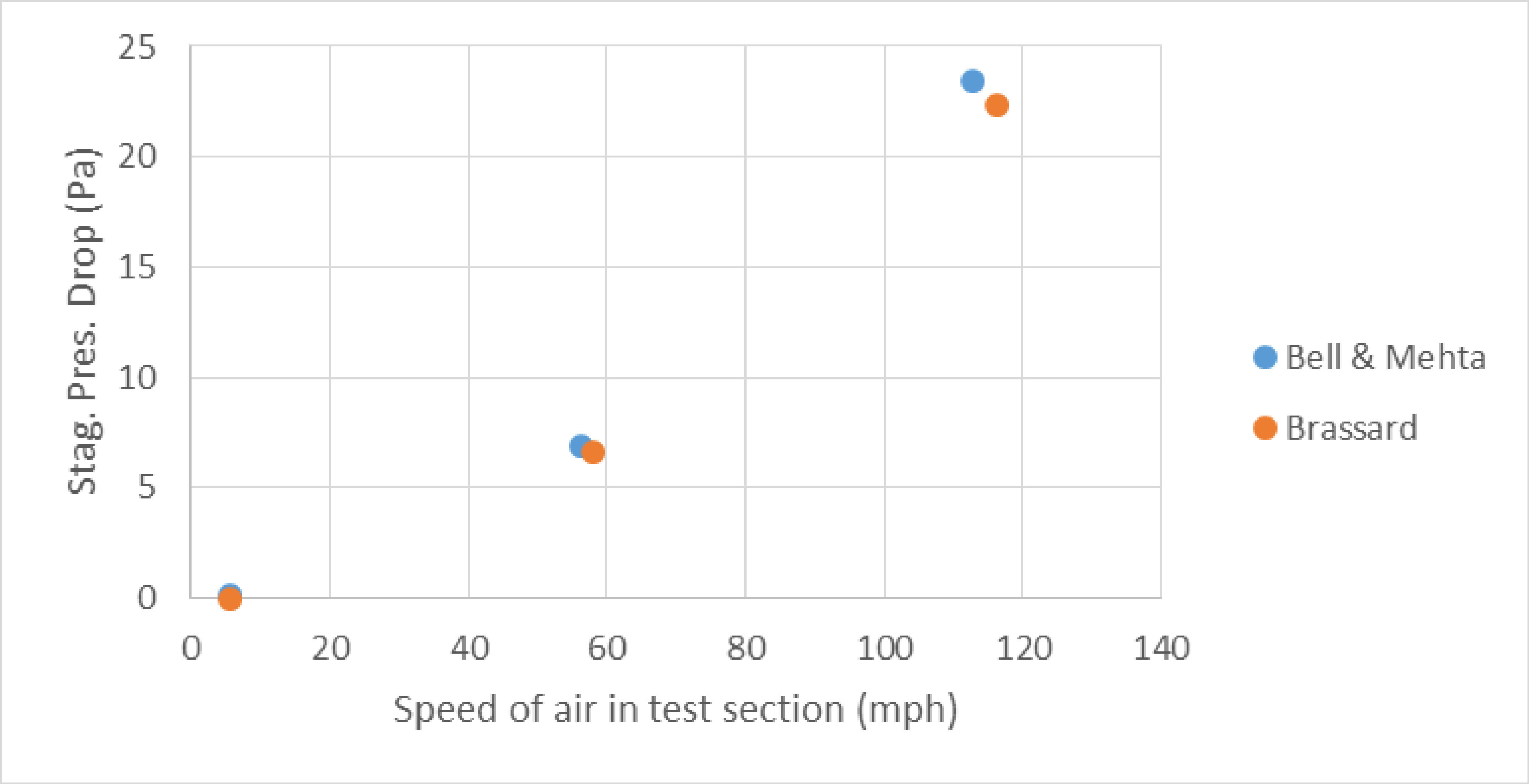


Simulation Analysis

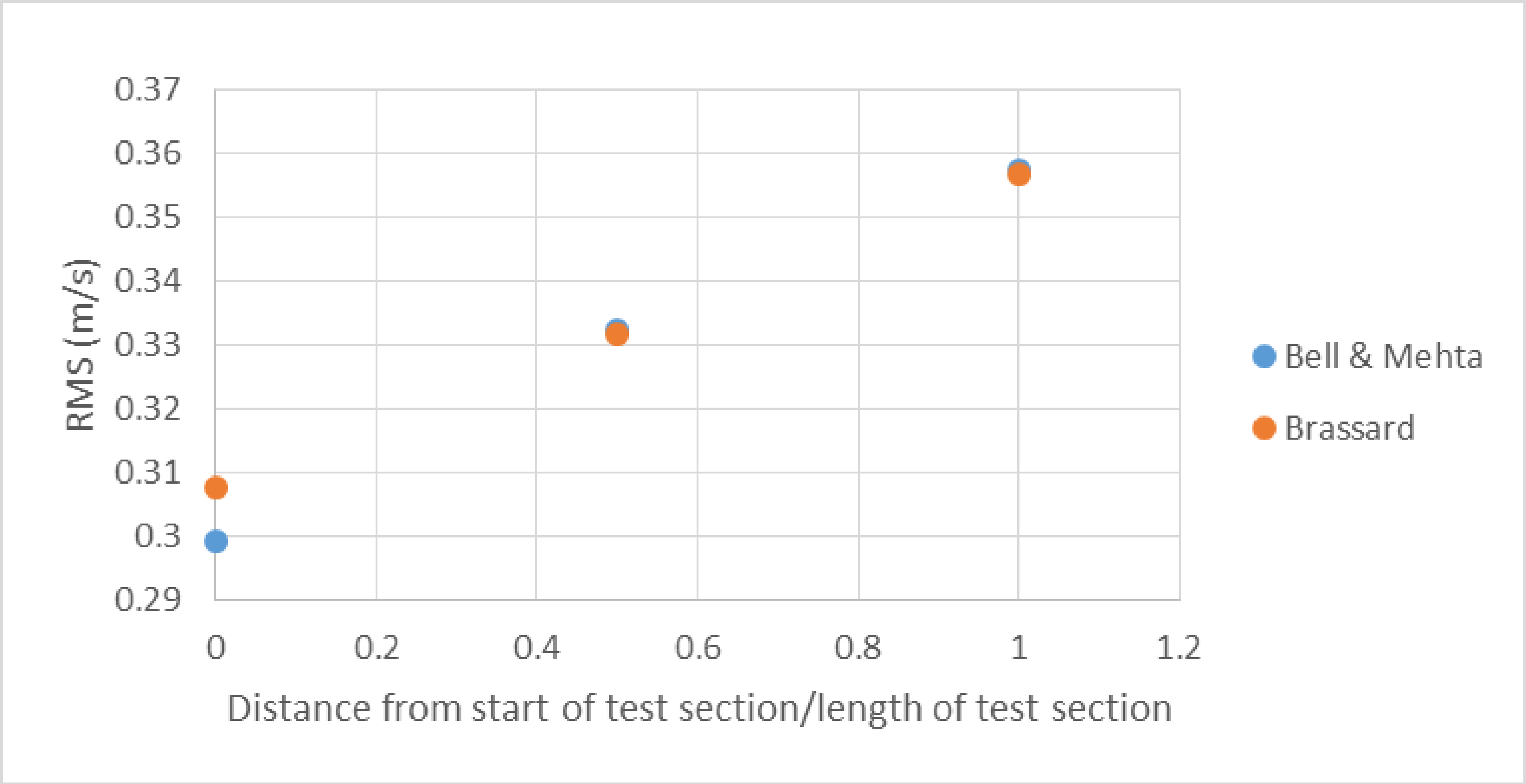
- Stagnation pressure drop across nozzle
- Test section flow uniformity
  - RMS values of planes at start, middle, and end of test section



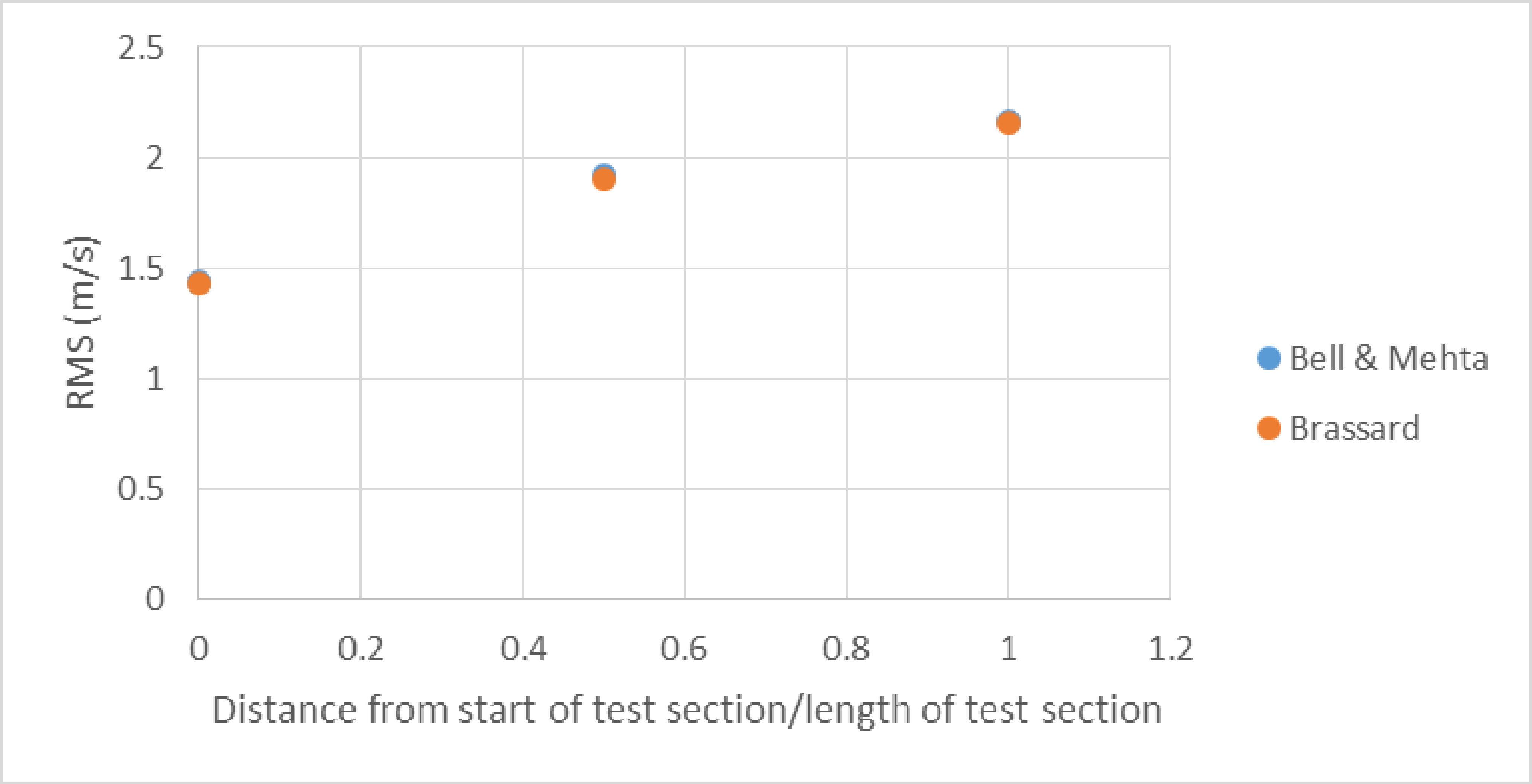
Stagnation Pressure Drop Across Nozzles



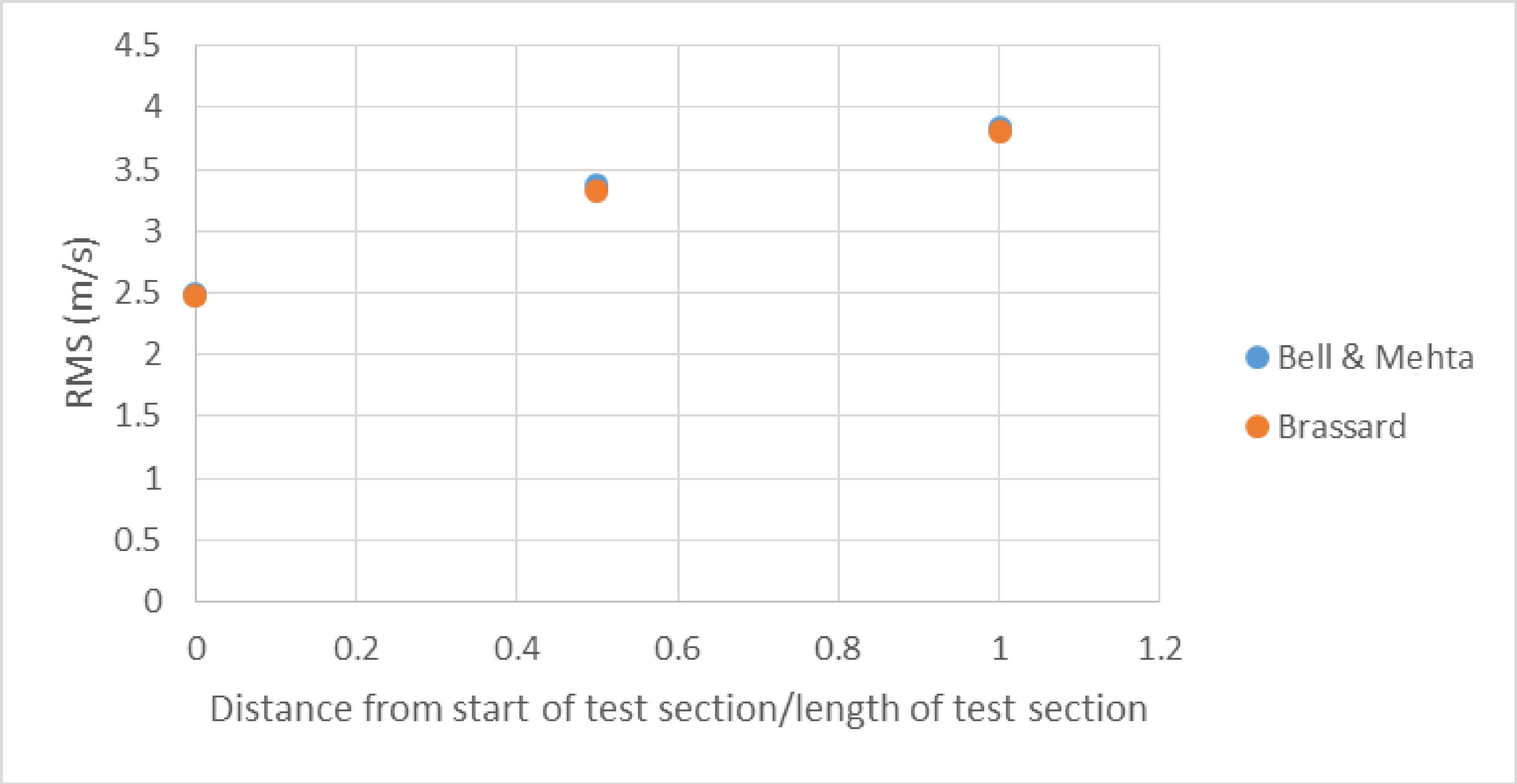
RMS values for 5 mph simulations



RMS values for 50 mph simulations

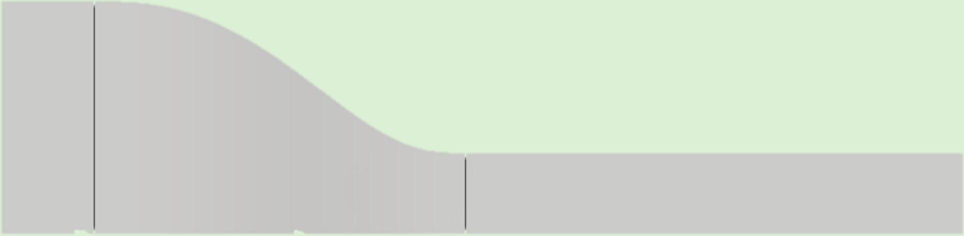


RMS values for 100 mph simulations

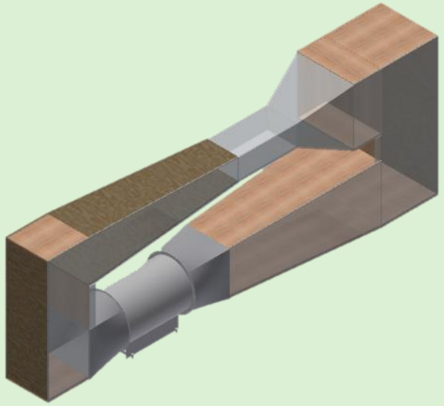


Conclusions

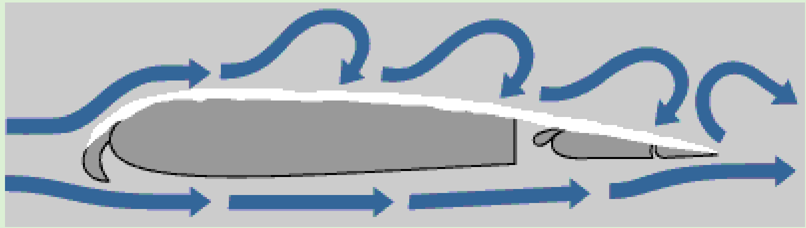
- Brassard nozzle achieved better simulation results



- Construction of wind tunnel



- Future use of wind tunnel



http://www.boeing.com/commercial/aeromagazine/aero_08/deice_fig01.html

Thank You

- Houghton College
- Dr. Aikens
- Jonathan Jaramillo, Daniel Eager, Jonathan Durbin, Leslie Hull

- References:

  - M. Van Dyke, *An Album of Fluid Motion*, (The Parabolic Press, Stanford, CA, 1982) p. 89.
  - J. H. Bell and R. D. Mehta, “Contraction Design for Small Low-Speed Wind Tunnels,” NASA (1988).
  - D. Brassard and M. Ferchichi, “Transformation of a Polynomial for a Contraction Wall Profile,” Journal of Fluids Engineering 27, 183-185 (2005).