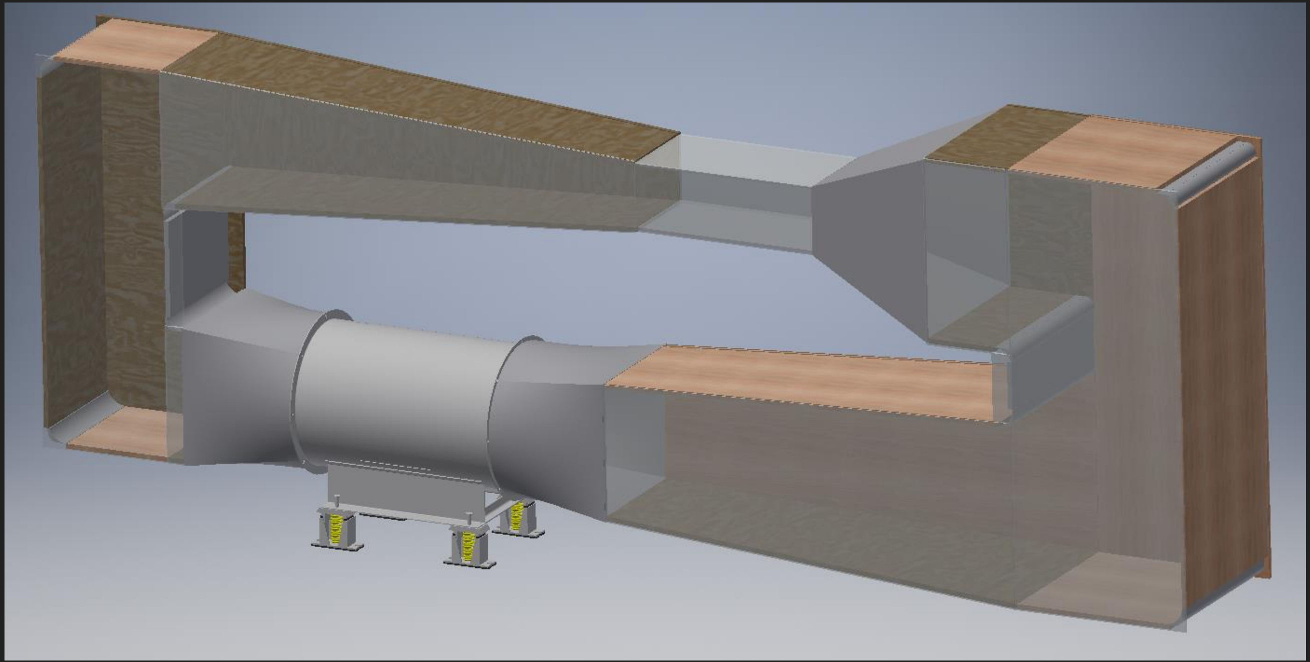
CONSTRUCTION OF A LOW-SPEED CLOSED-RETURN WIND TUNNEL

Jon Durbin and Dr. Kurt Aikens



Motivation

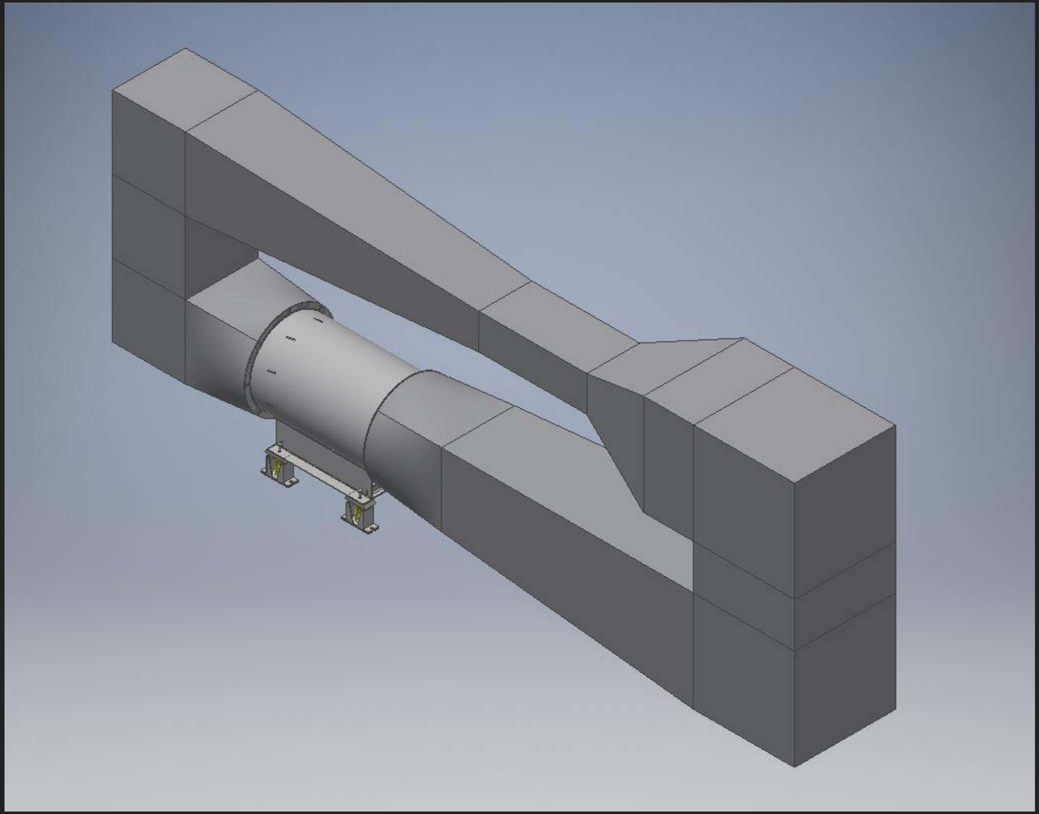
Wind tunnel at Houghton College
- Student research
- Laboratories

Important tool for fluid dynamicists

My project:
- Refine overall design
- Build parts

Overview

- Theory
- General Wind Tunnel
- Houghton’s Wind Tunnel
- Design Considerations
- Current Progress
- Conclusions



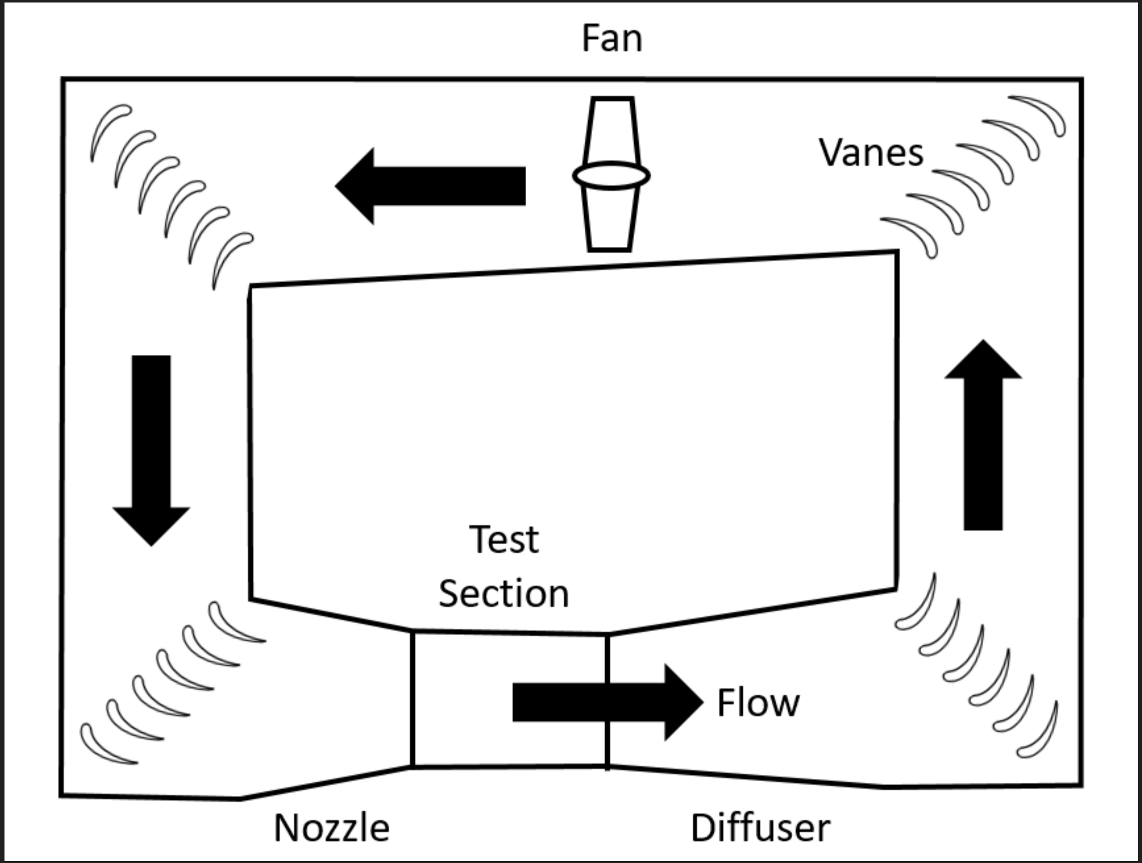
Governing Equations

Continuity equation and Navier-Stokes equations:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_k}(\rho u_k) = 0$$

$$\frac{\partial(\rho u_j)}{\partial t} + \frac{\partial(\rho u_j u_k)}{\partial x_k} = \frac{\partial}{\partial x_i}\left\{-p\delta_{ij} + \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \delta_{ij}\frac{2}{3}\frac{\partial u_k}{\partial x_k}\right)\right\}$$

General Wind Tunnel



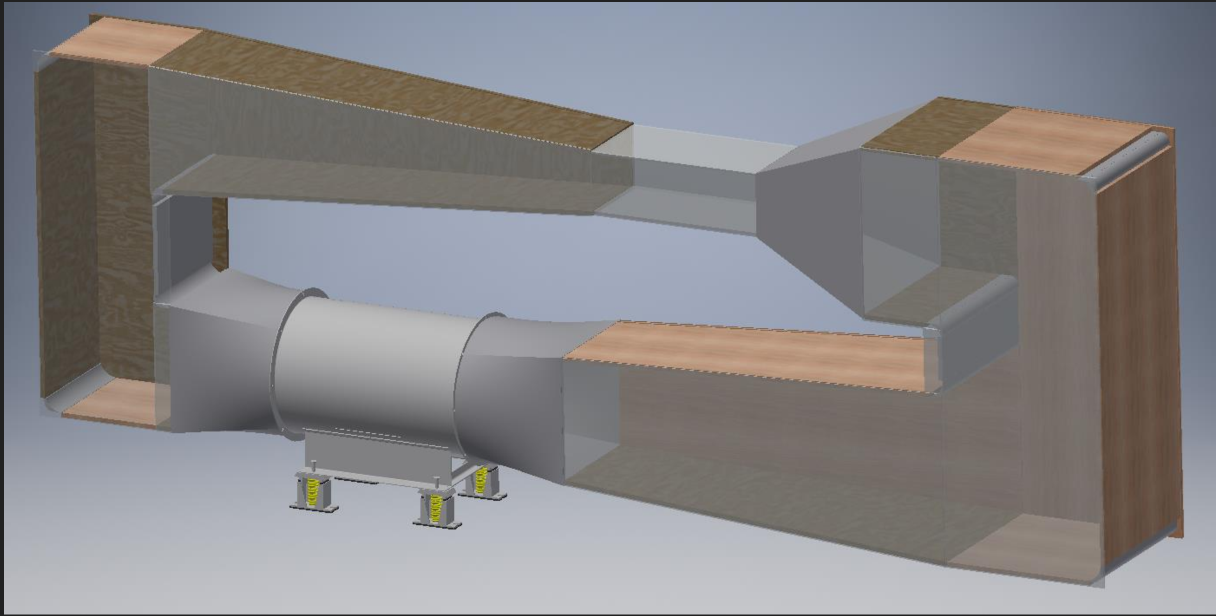
Our Wind Tunnel

Design considerations:

- Space constraints
- 16 ft. long,
- 6 ft. tall,
- 3 ft. wide.

Test section:

- Speed: 100 mph
- 29 in. long,
- 9.5 in. tall,
- 14 in. wide.

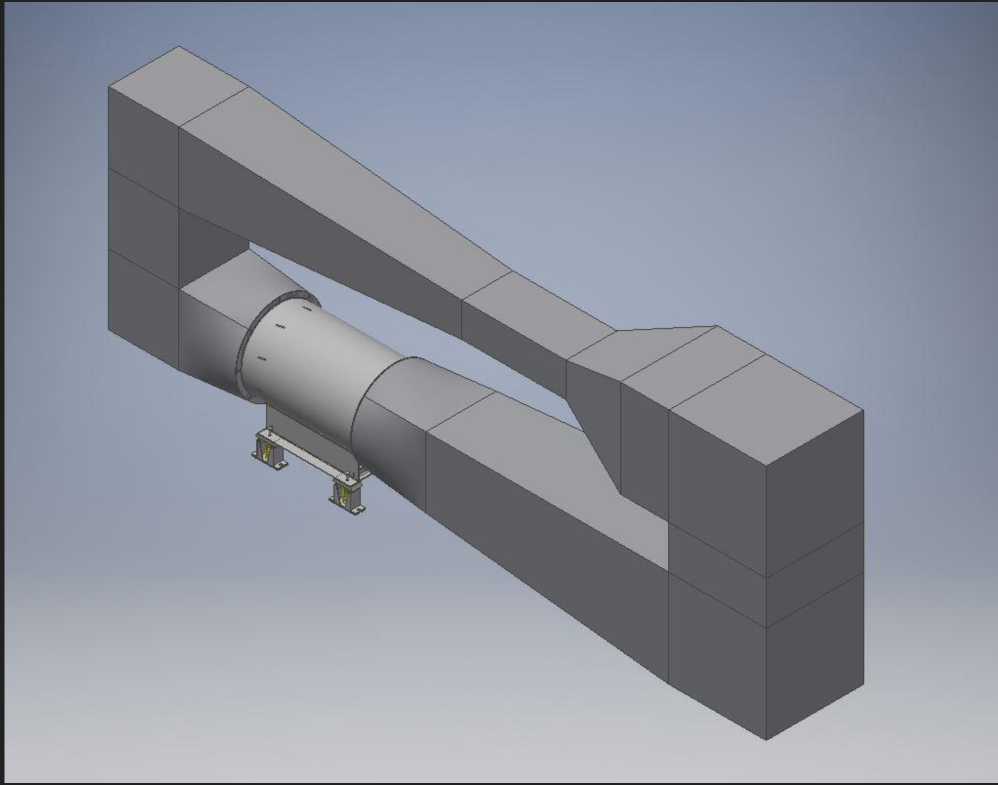


Initial Design

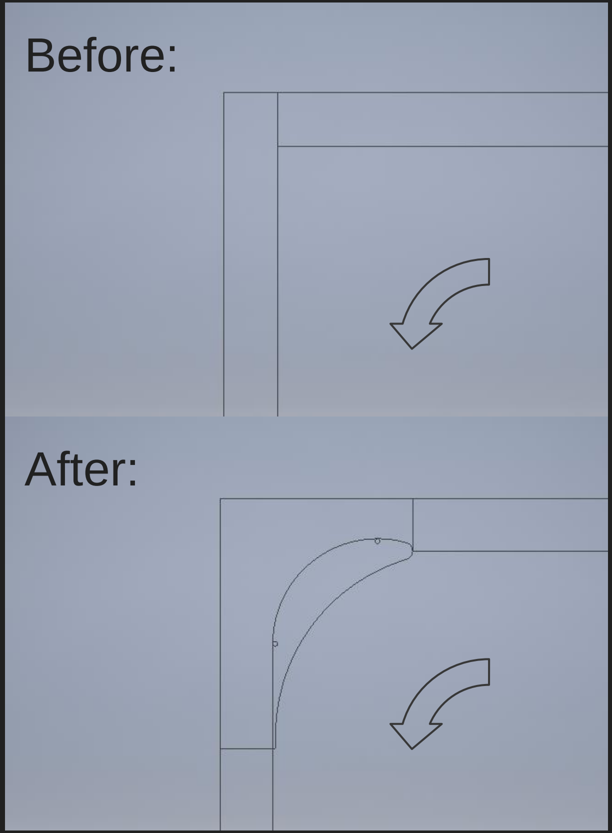
Initial design completed by
Jonathan Jaramillo

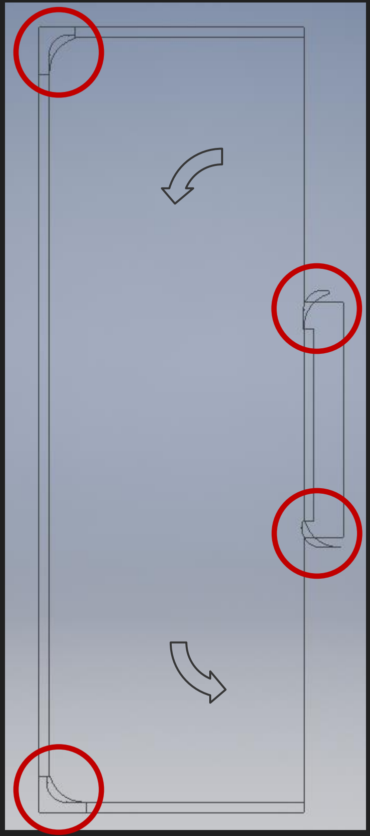
Corner vanes researched by
Dan Eager

Nozzle researched by
Jeremy Martin

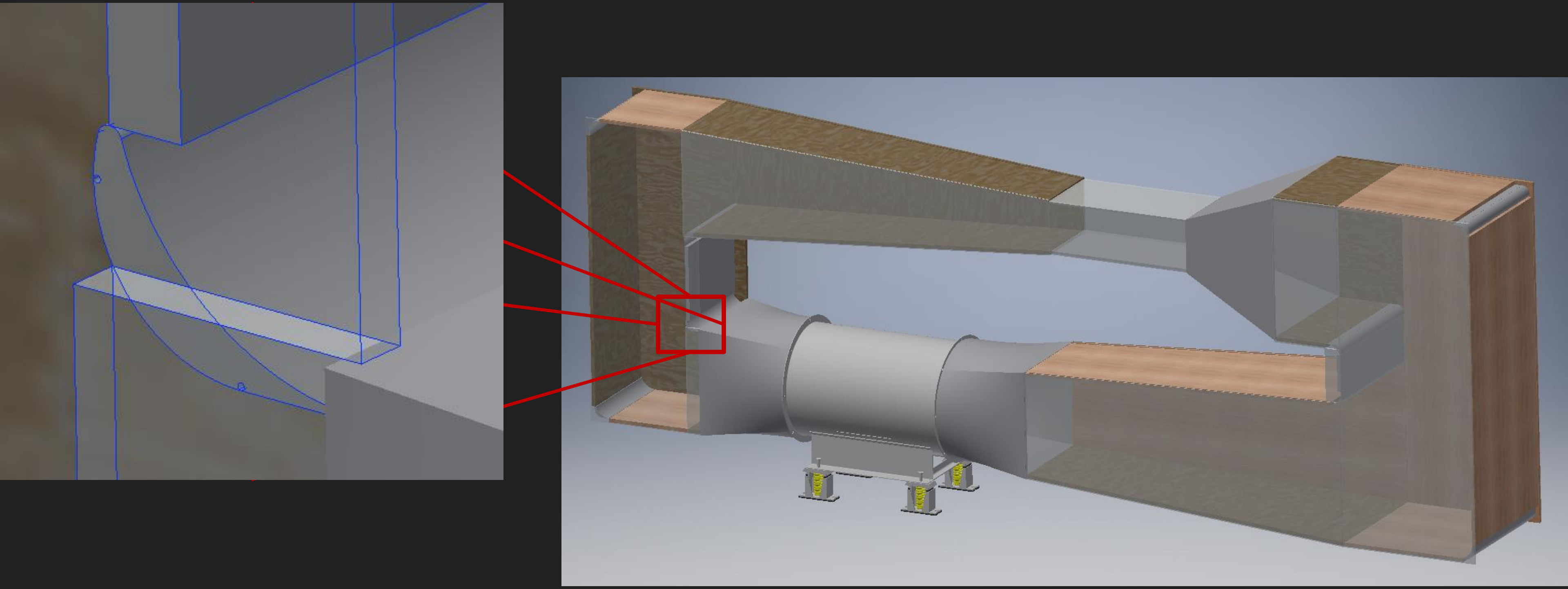


My Work: Vanes and Diffusers

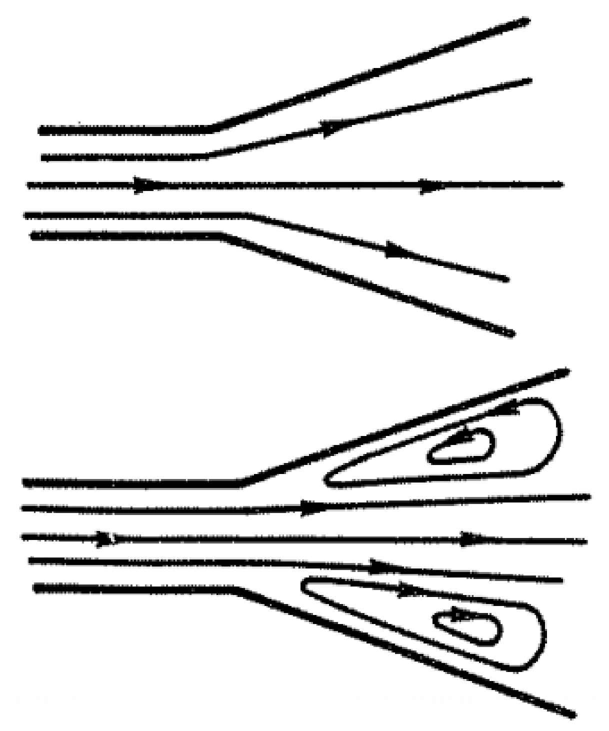


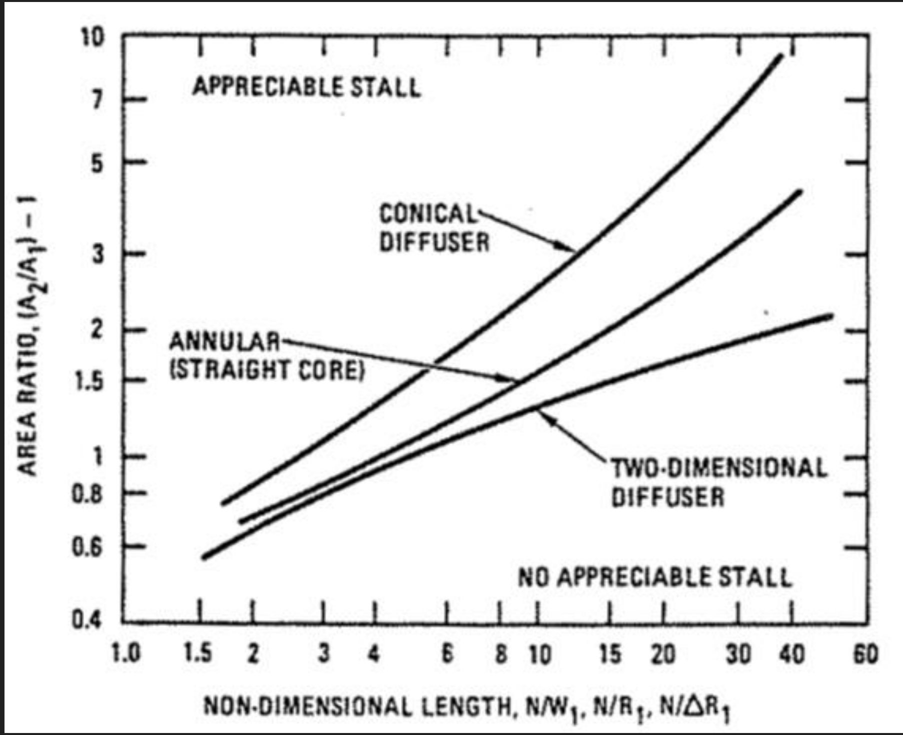


My Work: Vanes and Diffusers (Contd.)



My Work: Vanes and Diffusers (Contd. 2)





Figures taken from: R. D. Blevins, *Applied Fluid Dynamics Handbook*, (Van Nostrand Reinhold Co., New York, 1984).

Construction Progress

Conclusions

Much more work to be done

Complete:

One diffuser, small corners

Incomplete:

Smaller diffuser, test section

Larger corners, nozzle

Further research into nozzle, test section

Shape of nozzle

Recording data from object in test section

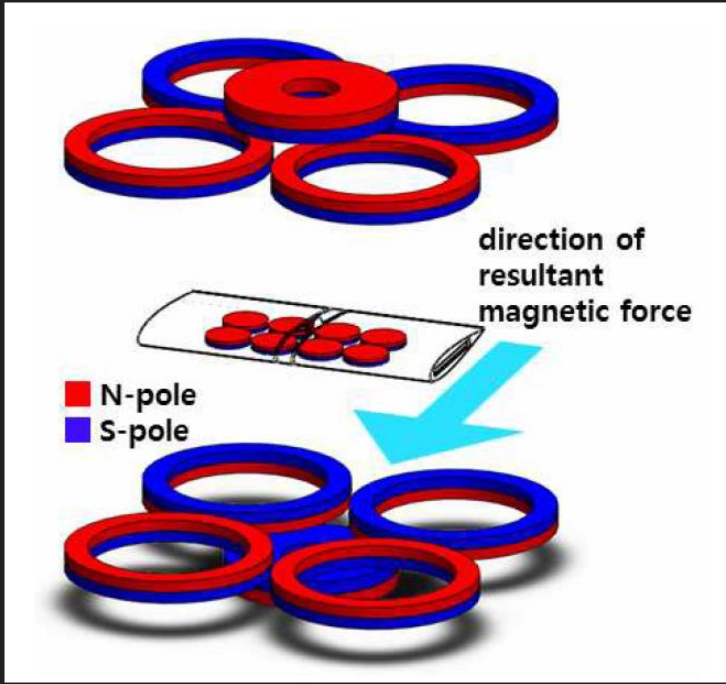
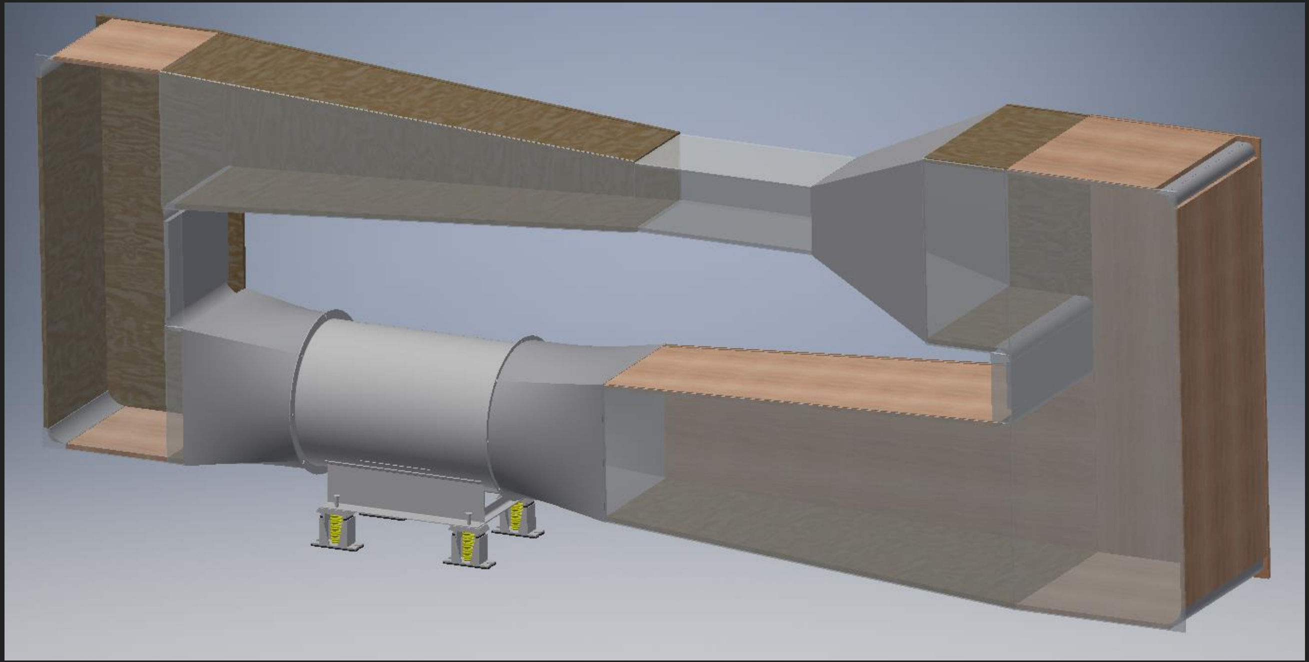


Figure taken from: D-K Lee, J-S Lee, J-H Han, and Y Kawamura, J. Mech. Sci. and Tech. **27** (2013)

Acknowledgements

Dr. Aikens

Houghton College



References

D. D. Baals and W. R. Corliss, *Wind Tunnels of NASA* (U.S. Government Printing Office, Washington, D.C., 1981).

W. T. Eckert, K. W. Mort and J. Jope, NASA TN D-8243 (1976).

R. D. Blevins, *Applied Fluid Dynamics Handbook*, (Van Nostrand Reinhold Co., New York, 1984).

D-K Lee, J-S Lee, J-H Han, and Y Kawamura, J. Mech. Sci. and Tech. **27** (2013).

J. D. Jaramillo, B.S. Thesis, Houghton College, 2017.

D. J. Eager, B.S. Thesis, Houghton College, 2018.

J. S. Martin, B.S. Thesis, Houghton College, 2019.

History and Motivation

Frank Wenham (1824-1908)

- First wind tunnel in 1871

Wright Brothers

- Open-return wind tunnel
- Practically a box
- Possibilities are endless

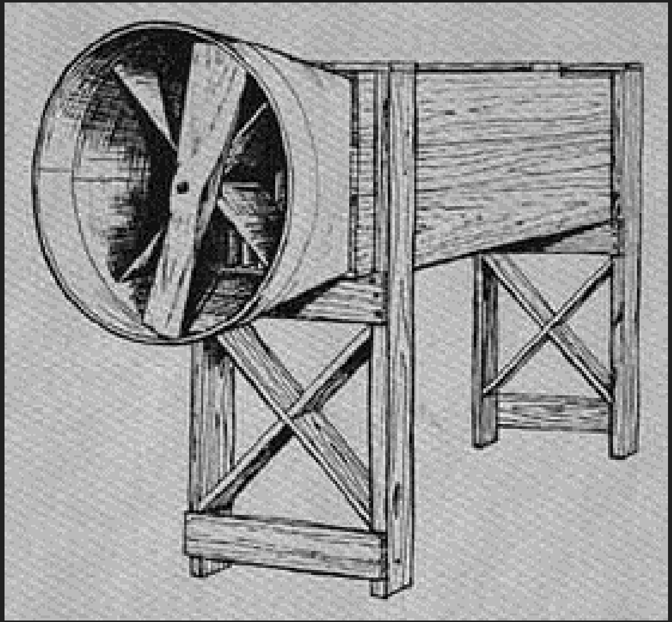


Figure taken from D. D. Baals and W. R. Corliss, Wind Tunnels of NASA (U.S. Government Printing Office, Washington, D.C., 1981).

Governing Equations (Non-Dimensionalized)

Continuity equation and Navier-Stokes equations:

$$\frac{\partial \rho'}{\partial t'} + \frac{\partial}{\partial x'_k}(\rho' u'_k) = 0$$

$$\frac{\partial(\rho' u'_j)}{\partial t'} + \frac{\partial(\rho' u'_j u'_k)}{\partial x'_k} = \frac{\partial}{\partial x'_i}\left\{-p'\delta_{ij} + \mu\left(\frac{\partial u'_i}{\partial x'_j} + \frac{\partial u'_j}{\partial x'_i} - \delta_{ij}\frac{2}{3}\frac{\partial u'_k}{\partial x'_k}\right)\right\}$$

Experimental/Computational Fluid Dynamics

Similarity Parameters

- Reynolds number
- Mach number
- Other numbers

$$\mathrm{Re} = \frac{\rho_\infty U_\infty L}{\mu_\infty}$$

$$\mathrm{M} = \frac{U_\infty}{a_\infty} = \frac{U_\infty}{\sqrt{\gamma R T_\infty}}$$

Empirical Correlations

- Loss coefficients
  - Must minimize
- General form:

$$K_i = \frac{\Delta p_T}{q}$$

Image here?
Maybe general wind tunnel, to show components better.

Our Corner Vanes