



## **Activity: Build Your Own Wind Tunnel**

### **Introduction**

Wind engineers investigate the interaction between wind and the natural and built environments by combining knowledge from several disciplines, including structural engineering, mechanical engineering, meteorology, and applied physics. Wind flows can be both beneficial and damaging to mankind. For example, turbines can harness wind energy and convert it into useful electricity, whereas extreme wind events such as hurricanes and tornadoes can inflict major damage to entire communities. The Wall of Wind (WOW) at FIU is an experimental wind engineering facility working to improve building performance in hurricane-prone regions. The WOW facility is capable of generating winds in excess of 150 mph for testing building components and large-scale building models.

In general, wind tunnels exist to study complex aerodynamic interactions that are otherwise difficult to analyze from a solely theoretical or computational approach. Wind tunnels have been created in many styles and sizes, with their designs governed by the overall aerodynamic goal of the wind tunnel and the available budget. Since the mid-twentieth century, wind tunnel testing has become the primary method for establishing wind loading provisions used in building codes and standards. Wind tunnel testing has also become a cost-effective approach for determining the wind loading on large structures (tall buildings, long-span bridges, stadiums, etc.) on a case-by-case basis. Typically, scaled models and/or section models of a large structure are tested in the wind tunnel, allowing details such as the structure's shape, location, and surrounding terrain to be considered.

This activity outlines the construction of a small low-speed wind tunnel that teachers may apply in the context of a high school science classroom. It is our desire that access to this wind tunnel will enhance students' understanding of flow types (laminar vs. turbulent), flow patterns around different objects, the conservation of mass and conservation of energy (Bernoulli's equation) principles, aerodynamic lift and drag, and how wind interactions affect our daily lives.

### **Basic Activity: Build Your Own Wind Tunnel**

See materials list.

#### ***Procedure***

1. Create Flow Straightener:
  - a. Use Gorilla tape to tape 9 tubes together in a row. Note: this should be the same width as your fan.
  - b. Make 9 rows of 9 tubes.
  - c. Connect the completed 9 rows together



(a)



(b)



(c)

2. Create Contraction and Diffuser segments (exactly the same dimensions and procedure)
  - a. Cut all pieces to size (see attached drawings)
  - b. Connect pieces a small piece of Gorilla tape. Note: walls (slightly smaller pieces) will sit inside the edge of the bottom and top pieces (slightly larger pieces)
  - c. Run a line of hot glue along all of the inside edges of the section
  - d. Initial completed section



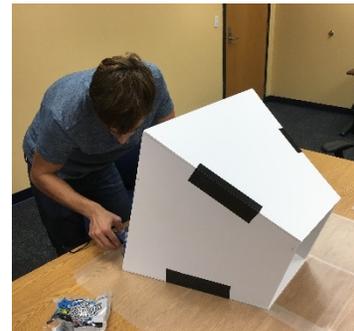
(a)



(b)

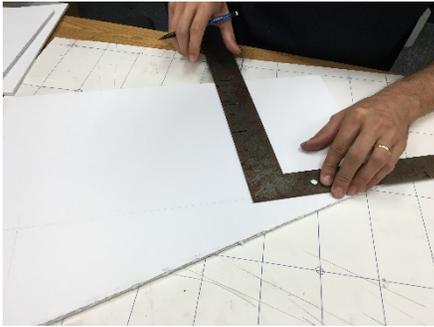


(c)

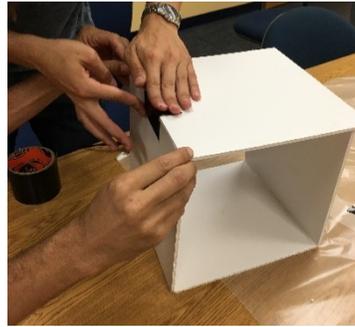


(d)

3. Create Working Section (Qty. 2)
  - a. Cut all pieces to size (see attached drawings)
  - b. Connect pieces a small piece of Gorilla tape. Note: walls (slightly smaller pieces) will sit inside the edge of the bottom and top pieces (slightly larger pieces)
  - c. Run a line of hot glue along all of the inside edges of the section



(a)



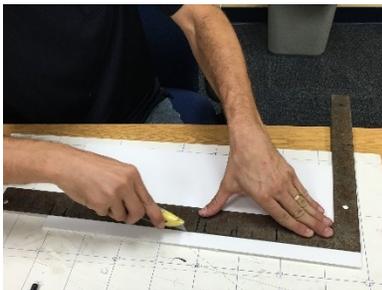
(b)



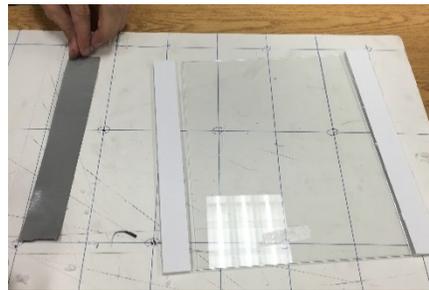
(c)

4. Create Test Section (Qty. 1 or 2)

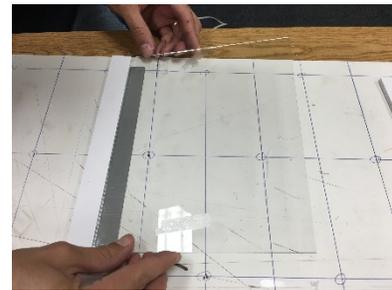
- a. Cut all pieces to size (see attached drawings)
- b. Cut a piece of Gorilla tape at about 8" and lay it flat (sticky side up)
- c. Place strip down on tape and line up glass to be flush with the foamboard strip



(a)

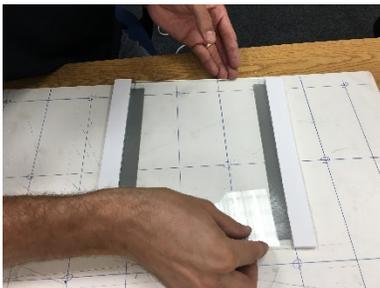


(b)



(c)

- d. Repeat for other side
- e. Seal other side with a strip of hot glue
- f. Repeat for second glass wall



(d)

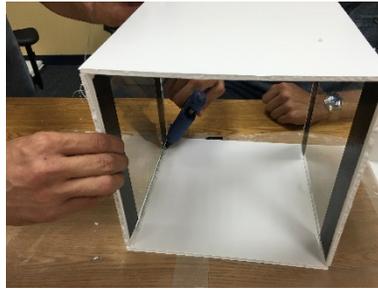


(e)



(f)

- g. Connect all four sides together



(g)

## 5. Add Connection Ribs

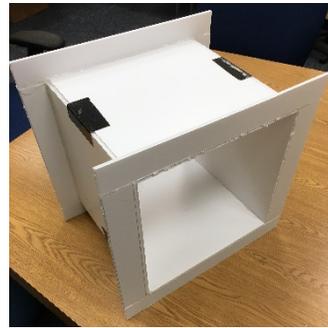
- a. Cut all pieces to size (see attached drawings), 1.5" strips were used in the demonstration model
- b. Attach ribs to outside by placing a strip of hot glue onto the strip and attaching it to the section. Then run another strip of hot glue down the inside.
- c. Finish attaching ribs on all sides of all sections.



(a)



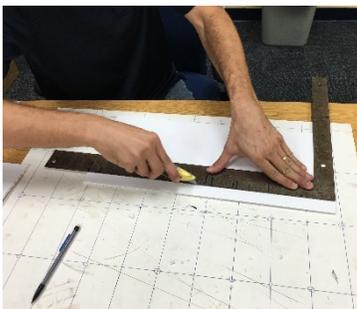
(b)



(c)

## 6. Create enclosure and ribbing for Flow Straightener

- a. Cut all pieces to size (see attached drawings)
- b. Use hot glue to attach all four wall pieces together
- c. Slide flow straightener into the enclosure; add hot glue as needed to secure



(a)



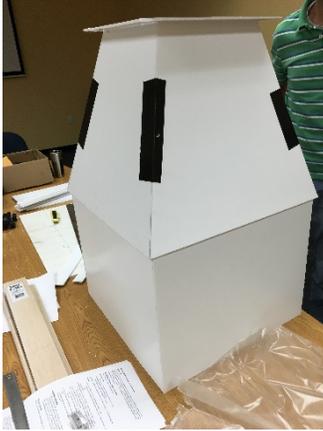
(b)



(c)

- d. Place Contractor on Flow Straightener and make a mark around the bottom

- e. Glue ribs around the flow straightener on this mark
- f. Finish adding ribs and extra ribbing on the bottom



(d)



(e)



(f)

7. Drill or punch holes in the connector ribs to help with connection between segments
  - a. Measure the location of holes on all four sides (on one side of connection)
  - b. Drill or punch holes in all four locations
  - c. Place adjacent pieces against each other (lining up the inside of the tunnel) and mark the location of the holes of the adjacent connector piece
  - d. Drill or punch these holes
  - e. Repeat for all segment connections



(a)



(b)



(c)

8. Connect all adjacent segments with bolts





9. Finished wind tunnel



**Possibilities Modifications**

1. *Different Materials:* The wind tunnel can be made out of any alternate materials (metal sheet, plywood, etc.).
2. *Different Scales:* Larger wind tunnels can be made with larger budgets. Simply scale up all of the given dimensions.

**Accompanying Activities**

1. Determine the wind speed in the test section with a pitot tube and manometer.
2. Use smoke to visualize the flow around different objects.
3. Use smoke to visualize vortex shedding.
4. Investigate the uplift on various roof shapes (flat, gable, hip).
5. Investigate the lift and drag of an airfoil.
6. Design an airfoil to optimize the lift-to-drag ratio.
7. Design a vortex suppression device to reduce uplift on a flat roof.

**Materials for Build Your Own Wind Tunnel Activity**

**Wind Tunnel Parts:**

Part #	Product Description	Vendor	Quantity	Unit Price	Total Price	Purpose	URL
S-1182	Snap-Seal Tubes - 2 x 12", .060" thick	U-Line	100 (2 Packs of 50)	\$ 0.63	\$ 63.00	Flow Straighteners	<a href="http://www.uline.com/Product/Detail/S-1182/Tubes/Snap-Seal-Tubes-2-x-12-060-thick">http://www.uline.com/Product/Detail/S-1182/Tubes/Snap-Seal-Tubes-2-x-12-060-thick</a>
S-12857	Foamboard - 20 x 30", White	U-Line	25 (1 Carton of 25)	\$ 2.40	\$ 60.00	Wind Tunnel Walls, Roof, Floor	<a href="http://www.uline.com/Product/Detail/S-12857/Foam-Board/Foamboard-20-x-30-White">http://www.uline.com/Product/Detail/S-12857/Foam-Board/Foamboard-20-x-30-White</a>
60030	Gorilla Tape (2.88 in. x 30 yds. Tough and Wide Gorilla Tape)	Home Depot	1	\$ 14.97	\$ 14.97	Wind Tunnel Construction	<a href="http://www.homedepot.com/p/Gorilla-2-88-in-x-30-yds-Tough-and-Wide-Gorilla-Tape-60030/202528614">http://www.homedepot.com/p/Gorilla-2-88-in-x-30-yds-Tough-and-Wide-Gorilla-Tape-60030/202528614</a>
3733	Lasko 20 in. 3-Speed Box Fan	Home Depot	1	\$ 16.96	\$ 16.96	Wind Tunnel Fan	<a href="http://www.homedepot.com/p/Lasko-20-in-3-Speed-Box-Fan-3733/100405665">http://www.homedepot.com/p/Lasko-20-in-3-Speed-Box-Fan-3733/100405665</a>
90810	8 in. x 10 in. x .125 in. Clear Glass	Home Depot	4	\$ 2.98	\$ 11.92	Test Section Walls (for Viewing)	<a href="http://www.homedepot.com/p/8-in-x-10-in-x-125-in-Clear-Glass-90810/202091040">http://www.homedepot.com/p/8-in-x-10-in-x-125-in-Clear-Glass-90810/202091040</a>
<b>Grand Total:</b>					<b>\$ 166.85</b>		

**Instrumentation Items:**

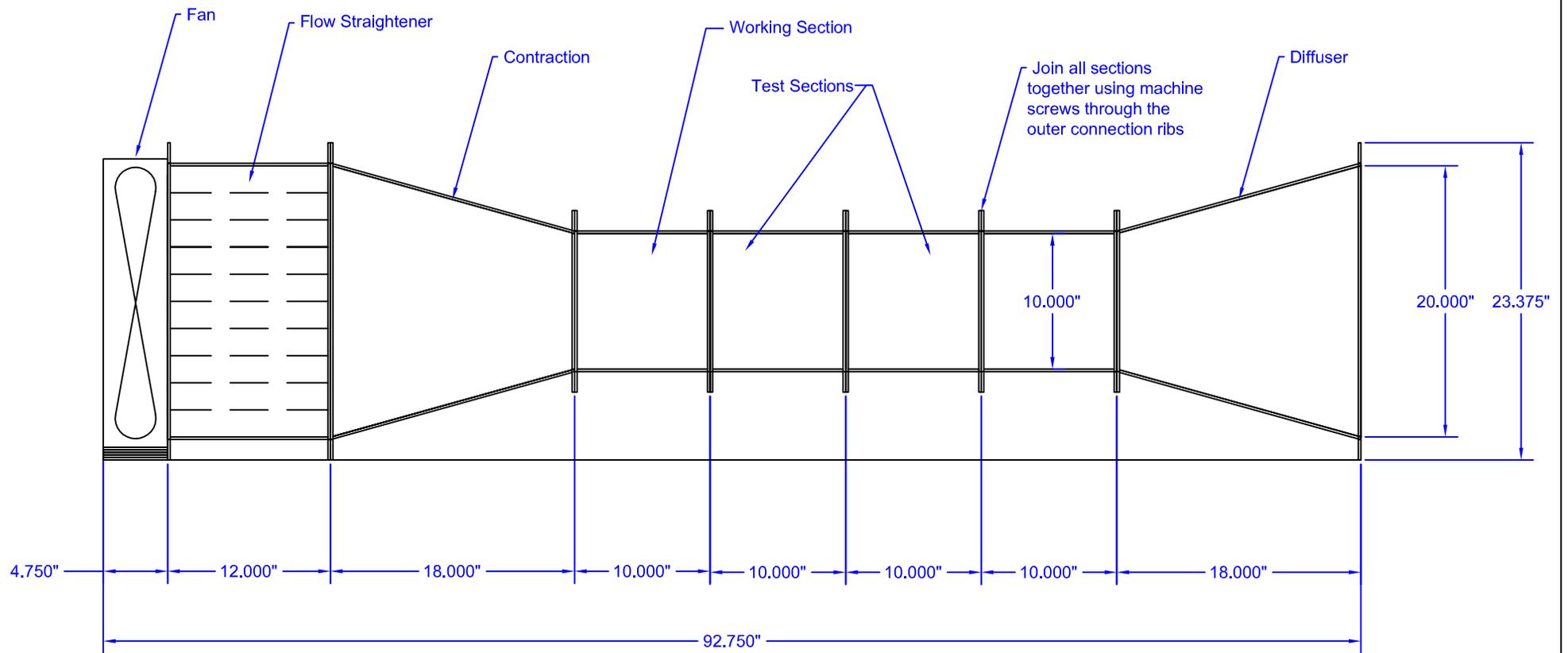
Part #	Product Description	Vendor	Quantity	Unit Price	Total Price	Purpose	URL
60332	Centech 1000 Gram Digital Scale	Harbor Freight	2	\$ 9.99	\$ 19.98	Force Measurements	<a href="http://www.harborfreight.com/1000-gram-digital-scale-60332.html">http://www.harborfreight.com/1000-gram-digital-scale-60332.html</a>
MARK II 25	Molded Plastic Manometers	Dwyer	1	\$ 35.25	\$ 35.25	Liquid Manometer (Pressure Measurements)	<a href="http://www.dwyer-inst.com/Product/Pressure/Manometers/Stationary/SeriesMarkII/Google?gclid=CjwKEAjw_LG8BRDb1JTxm8uP_UwSjADu_8pWIMj6X5cVtItaad_S315ZexadM11KI-XvvV-i6TVXoC087w_wcB">http://www.dwyer-inst.com/Product/Pressure/Manometers/Stationary/SeriesMarkII/Google?gclid=CjwKEAjw_LG8BRDb1JTxm8uP_UwSjADu_8pWIMj6X5cVtItaad_S315ZexadM11KI-XvvV-i6TVXoC087w_wcB</a>
<b>Grand Total:</b>					<b>\$ 55.23</b>		

**Items for Construction:**

Part #	Product Description	Vendor	Quantity	Unit Price	Total Price	Purpose	URL
60037	Retractable Utility Knife	Home Depot	1	\$ 1.98	\$ 1.98	Cut the foamboard	
1110	16 in. x 24 in. Steel Framing Square	Home Depot	1	\$ 6.96	\$ 6.96	Measure / draw lines / cut foamboard	<a href="http://www.homedepot.com/p/Empire-16-in-x-24-in-Steel-Framing-Square-1110/100204103">http://www.homedepot.com/p/Empire-16-in-x-24-in-Steel-Framing-Square-1110/100204103</a>
	CCbetter® Mini Hot Glue Gun with 25 pcs Melt Glue Sticks	Amazon	1	\$ 10.99	\$ 10.99	Connect and seal foamboard	<a href="https://www.amazon.com/CCbetter%C2%AE-Temperature-Melting-Flexible-Projects/dp/B01178RV12/ref=sr_1_4?ie=UTF8&amp;qid=1468522038&amp;sr=8-4&amp;keywords=hot+glue">https://www.amazon.com/CCbetter%C2%AE-Temperature-Melting-Flexible-Projects/dp/B01178RV12/ref=sr_1_4?ie=UTF8&amp;qid=1468522038&amp;sr=8-4&amp;keywords=hot+glue</a>
	Surebonder DT-100 Made in the USA All Purpose Stik-Mini Glue Sticks	Amazon	1	\$ 8.99	\$ 8.99	Refills for hot glue gun	<a href="https://www.amazon.com/Surebonder-DT-100-Sticks-All-Temperature-5-Sticks-100/dp/B003ZII34/ref=pd_bxgy_201_img_2?ie=UTF8&amp;psc=1&amp;refRID=RJ43MT69JNZNDT4FSGSZ">https://www.amazon.com/Surebonder-DT-100-Sticks-All-Temperature-5-Sticks-100/dp/B003ZII34/ref=pd_bxgy_201_img_2?ie=UTF8&amp;psc=1&amp;refRID=RJ43MT69JNZNDT4FSGSZ</a>
	Scrap board (dedicate one of foamboard pieces as cutting board)					Cutting foamboard	
	Machine screws, washers, and nuts	Home Depot					
	Two-sided tape	Home Depot					

**Items for Smoke Visualization:**

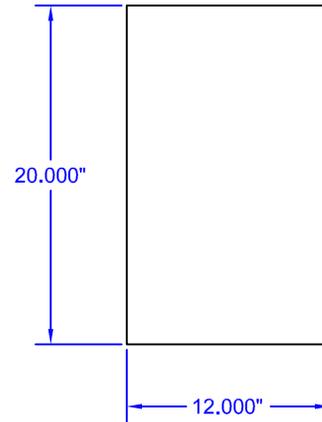
Part #	Product Description	Vendor	Quantity	Unit Price	Total Price	Purpose	URL
	Air Pump	Petsmart			\$ -		
	Airline Tubing	Petsmart	1	\$ 3.49	\$ 3.49		
	Gang Valve	Petsmart	1	\$ 5.49	\$ 5.49		
	Check Valve	Petsmart	1	\$ 2.99	\$ 2.99		
	Aluminum Rod	Tower Hobbies			\$ -		
	Glass Jar with lid	Michael's			\$ -		
	Incense Sticks	Michael's	1	\$ 1.99	\$ 1.99		



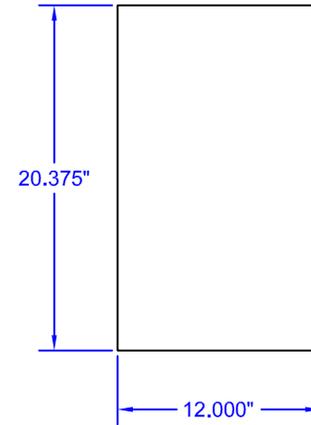
NOTE: The dimensions shown in these plans assumes the tunnel will be constructed from foam board approximately  $\frac{3}{16}$  inches thick. Some adjustment to the dimensions may be necessary if a different material or material thickness is used.

TITLE: Assembled Wind Tunnel - Side View	
DRAWN BY: JWE	DATE: 07 / 28 / 2016
SCALE: NTS	SHEET: 1 OF 7
FLORIDA INTERNATIONAL UNIVERSITY WALL OF WIND RESEARCH FACILITY	

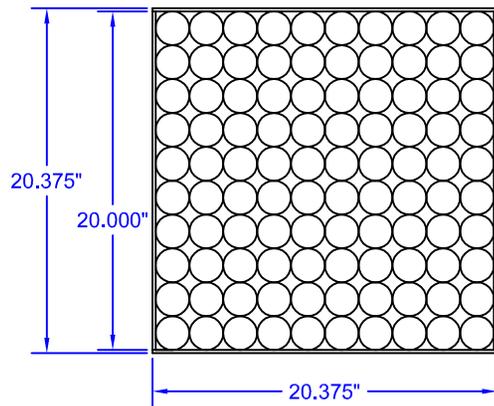
Cut pieces as shown to the right



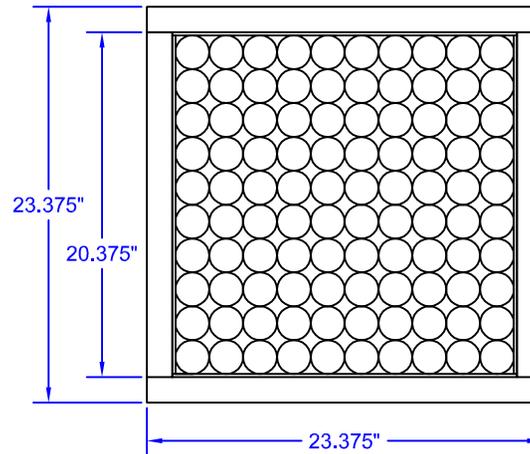
Wall Pieces  
(Qty. 2)



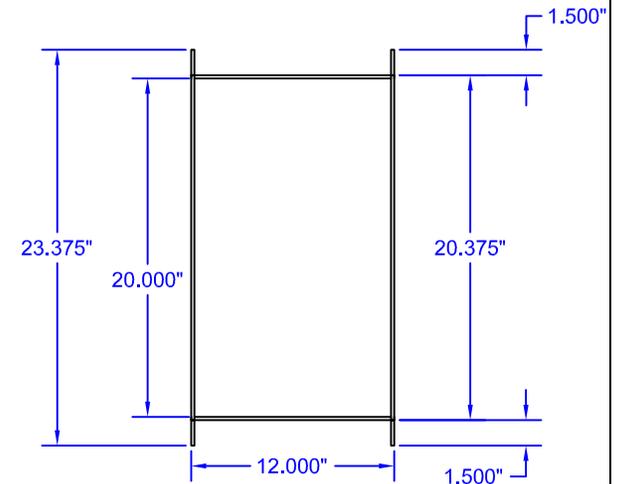
Floor and Roof Pieces  
(Qty. 2)



Front View of Flow Straightener Assembly  
(no connection ribs attached)



Front View of Flow Straightener Assembly  
(with connection ribs attached)

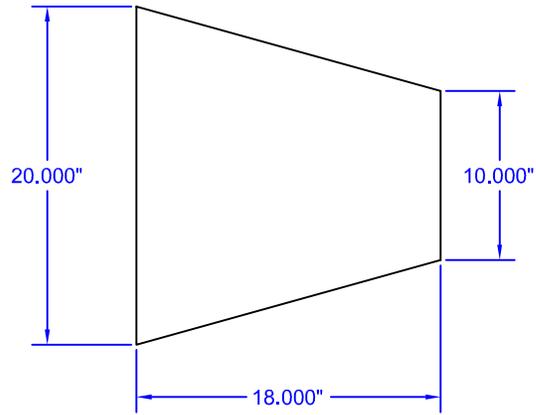


Side View of Flow Straightener Assembly  
(with connection ribs attached)

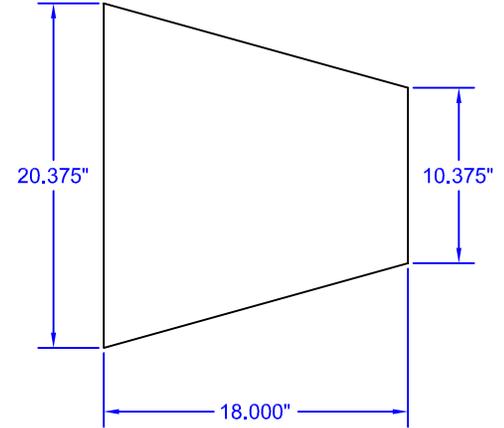
# Flow Straightener Section

TITLE: Flow Straightener Section Details	
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SCALE: NTS	SHEET: 2 OF 7
FLORIDA INTERNATIONAL UNIVERSITY WALL OF WIND RESEARCH FACILITY	

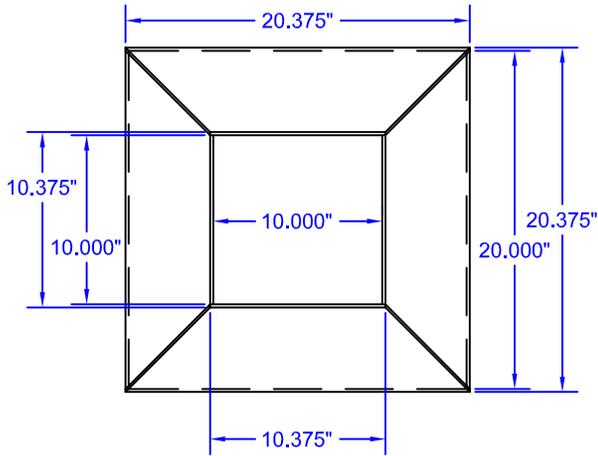
Cut pieces as shown to the right



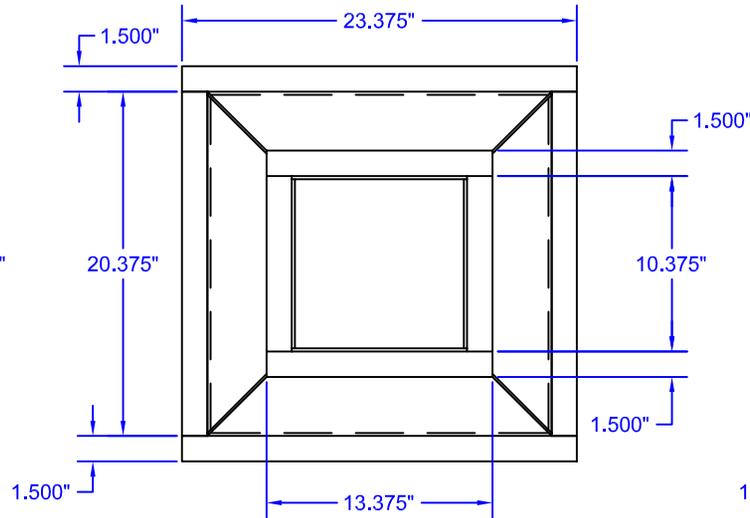
Wall Pieces  
(Qty. 2 for each section)



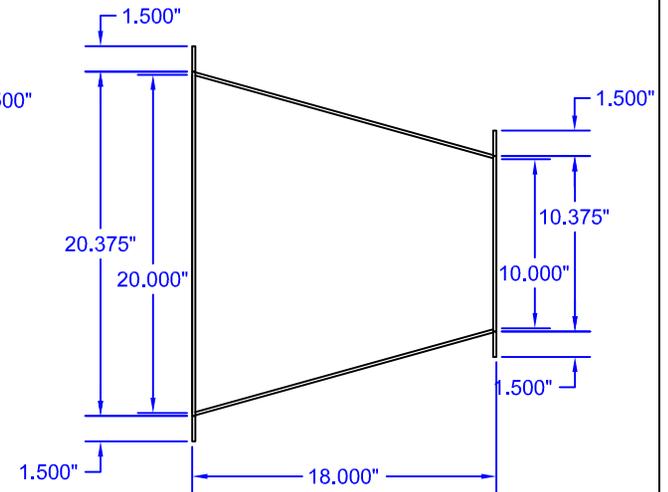
Floor and Roof Pieces  
(Qty. 2 for each section)



Front View of Contraction or Diffuser Assembly  
(no connection ribs attached)



Front View of Contraction or Diffuser Assembly  
(with connection ribs attached)

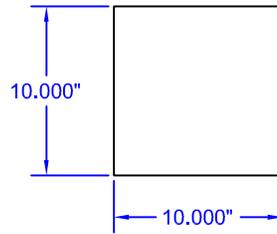


Side View of Contraction or Diffuser Assembly  
(with connection ribs attached)

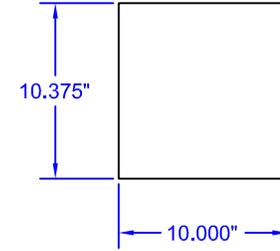
# Contraction and Diffuser Sections

TITLE: Contraction and Diffuser Section Details	
DRAWN BY: JWE	DATE: 07 / 28 / 2016
SCALE: NTS	SHEET: 3 OF 7
FLORIDA INTERNATIONAL UNIVERSITY WALL OF WIND RESEARCH FACILITY	

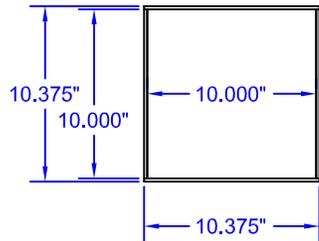
Cut pieces as shown to the right



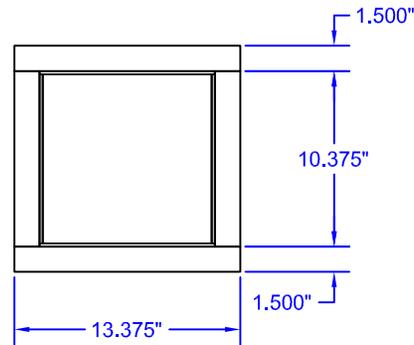
Wall Pieces  
(Qty. 2 for each section)



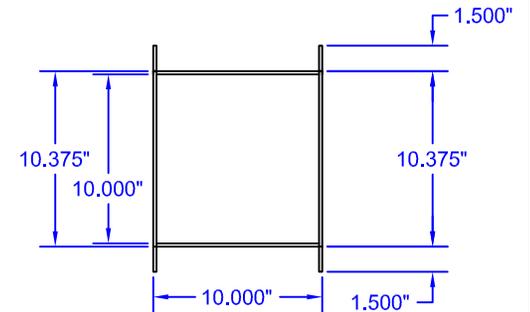
Floor and Roof Pieces  
(Qty. 2 for each section)



Front View of Working Section Assembly  
(no connection ribs attached)



Front View of Working Section Assembly  
(with connection ribs attached)

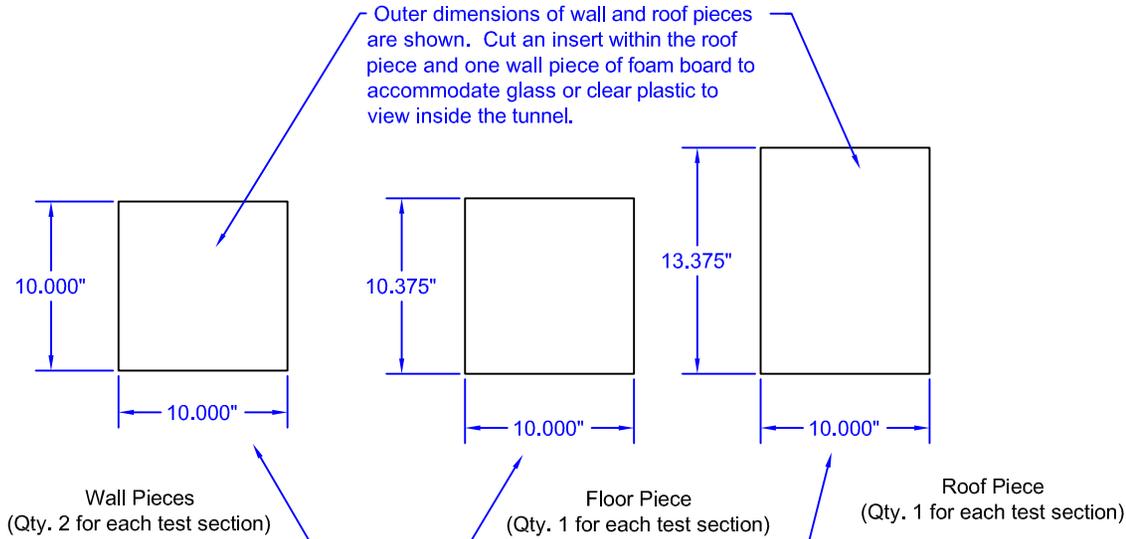


Side View of Working Section Assembly  
(with connection ribs attached)

# Working Sections

TITLE: Working Section Details	
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SCALE: NTS	SHEET: 4 OF 7
FLORIDA INTERNATIONAL UNIVERSITY WALL OF WIND RESEARCH FACILITY	

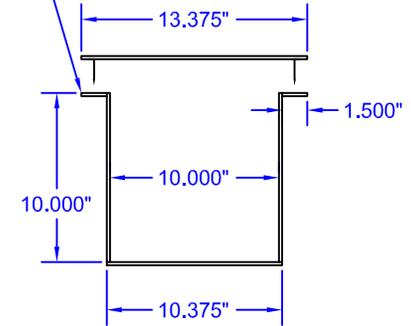
Cut pieces as shown below



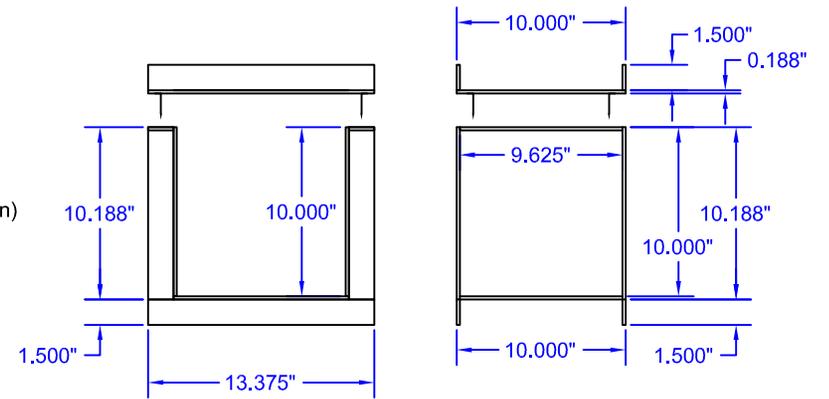
NOTES:

- 1) Test section may be constructed longer than 10 inches in length (side view) to create a longer test section with more visibility inside the wind tunnel
- 2) It is recommended to install low voltage LED lighting on the ceiling of the wind tunnel to improve visibility of smoke for flow visualization

Glue horizontal connection ribs to top of wall pieces. Use machine screws for removable roof-to-wall connection.



Front View of Test Section Assembly (no outer connection ribs attached)



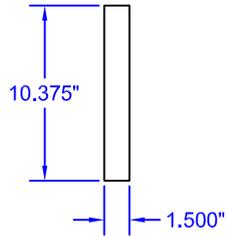
Front View of Test Section Assembly (with outer connection ribs attached)

Side View of Test Section Assembly (with outer connection ribs attached)

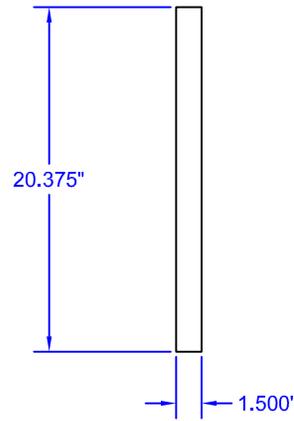
# Test Section

TITLE: Test Section Details	
DRAWN BY: JWE	DATE: 07 / 28 / 2016
SCALE: NTS	SHEET: 5 OF 7
FLORIDA INTERNATIONAL UNIVERSITY WALL OF WIND RESEARCH FACILITY	

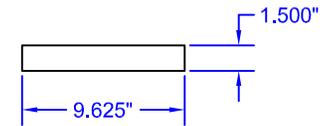
Cut pieces as shown



Wall ribs for Working Section, Test Section, and smaller side of Contraction and Diffuser

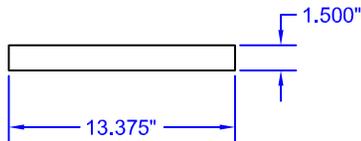


Wall ribs for Flow Straightener and larger sides of Contraction and Diffuser

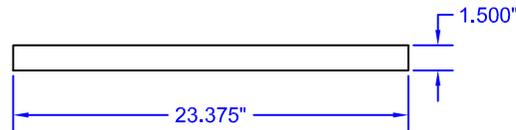


Horizontal ribs for Test Section roof attachment.

Note: The length of this rib will change if a test section longer than 10 inches is constructed.



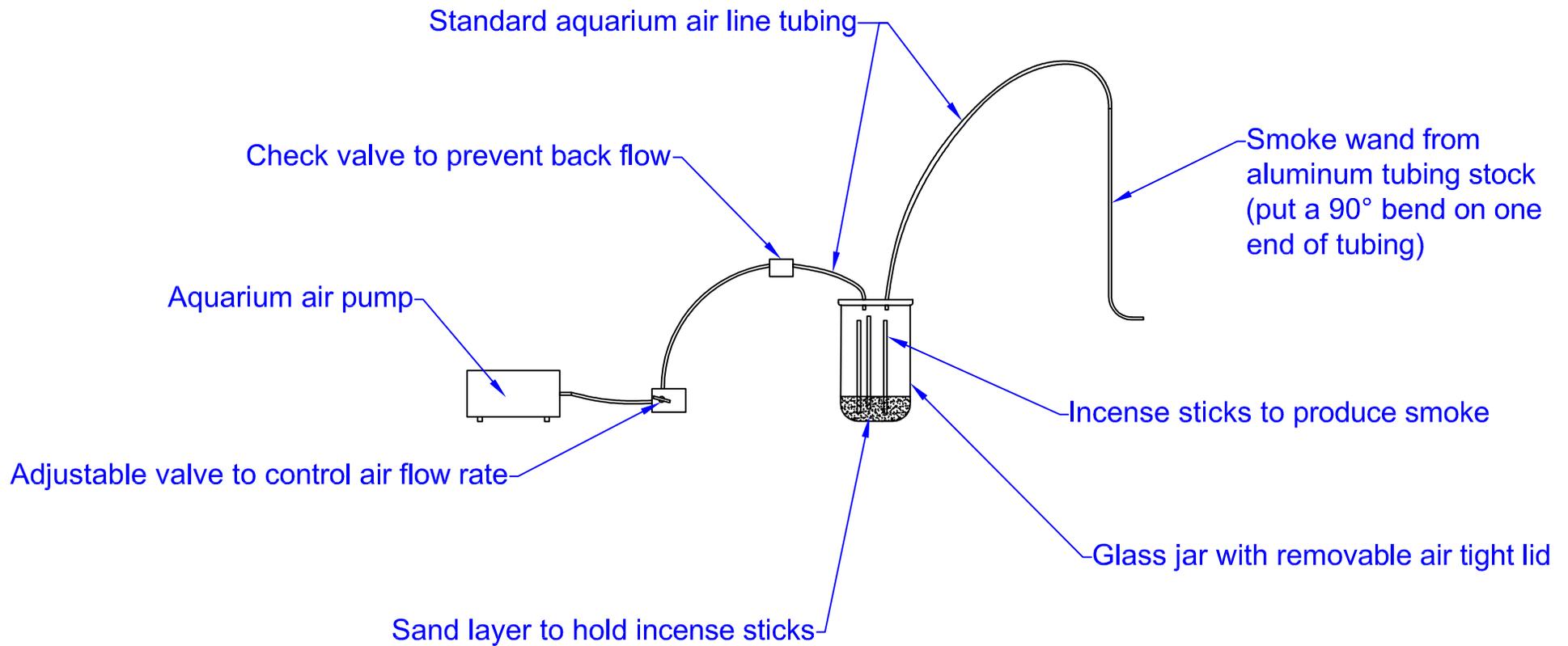
Floor and roof ribs for Working Section, Test Section, and smaller side of Contraction and Diffuser



Floor and Roof Ribs for Flow Straightener and larger sides of Contraction and Diffuser

## Connection Ribs

TITLE: Connection Rib Details	
DRAWN BY: JWE	DATE: 07 / 28 / 2016
SCALE: NTS	SHEET: 6 OF 7
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TITLE: Smoke Visualization Device	
DRAWN BY: JWE	DATE: 07 / 28 / 2016
SCALE: NTS	SHEET: 7 OF 7
FLORIDA INTERNATIONAL UNIVERSITY WALL OF WIND RESEARCH FACILITY	