Build a Wind Tunnel

By Mike Fitzgerald mfitzger@doe.state.in.us

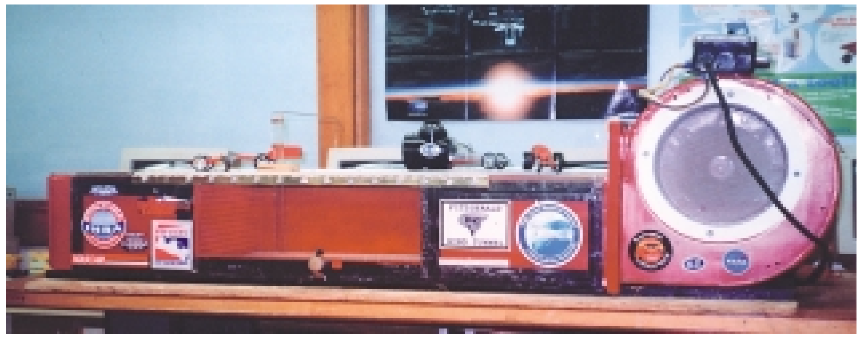

Photo 1—Completed wind tunnel

THIS article will give you basic information on constructing a wind tunnel that you can use for instructional activities with your students for many years to come. I will illustrate and describe the procedure and materials that I developed in constructing my own wind tunnel, but readers should view this information only as a guide.

I am not an expert at wind tunnel design nor am I an aerospace engineer. I am simply a teacher who wanted to use a wind tunnel with my students. I lacked enough funding to purchase a unit though a science or technology education supplier, so I built my own from bits and scraps! The wind tunnel that you construct may vary due to parts availability, your personal resourcefulness and your final design and construction techniques.

I started building the wind tunnel described here in 1998. While looking for a suitable fan unit, I learned that my father-in-law had an old unit in the storage shed buried beneath a mass of bicycles. Two weeks and about $200 of simple improvements later, I built my first wind tunnel based on the *TEA Wind Tunnel* plans (Chapin & Cook, 1988). I had received the plans as an undergraduate student from the Center for Implementing Technology Education at Ball State University. I recommend that you locate the *TEA Wind Tunnel* guide or a set of similar plans available via the Internet before beginning construction of your wind tunnel. I will include some basic illustrations, photographic details, supplier information and the recommendations that I would consider if I decide to construct another wind tunnel.

Background

Roberts (2001) describes hydrodynamics as the study of how fluids and gases move around an object. He further states that the study of hydrodynamics is important in that fluid movements help determine the shape and function of many vehicles. "A ship needs to slip through the water to move quickly. An automobile needs to divert air around its shell to improve fuel economy. An airplane needs to slow down the air traveling beneath its wings to create lift" (p. 10).

Konstantin Tsiolkovsky also experimented with the study of fluid movement, in 1892. He developed prototypes of wind tunnels that he used to study and measure aerodynamics concepts. His contributions helped lead to the understanding of aerodynamics employed by race car drivers, pilots and engineers today.

There are basically two kinds of wind tunnels. One pushes air around a test object, and the other kind pulls air over an object. Using a wind tunnel allows consistent testing of models in a test chamber, as well as for making measurements. Aerospace engineers use wind tunnels to study mockups and prototypes of aircraft, rockets and spacecraft. They collect data so they can design better aircraft. They may use a wind tunnel to study the flight characteristics of a mockup before spending money on a prototype aircraft. They also investigate such factors as the lift characteristics of the aircraft, how the control surfaces react at various speeds and the aircraft's drag characteristics. Aerospace designers perform these same activities on a prototype before flight testing to help ensure test pilots' safety.

You can learn more about wind tunnels by using software available on the NASA Glenn Research Center's web site: www.grc.nasa.gov/WWW/k-12/FoilSim download.html. The FoilSim program includes many lessons and activities that students can use to learn about aerospace topics. All activities are based on national standards in math, science and technology.

Architects and engineers also use wind tunnels to study the effect of aerodynamics on models of structures like skyscrapers and bridges. Aerodynamic forces on structures

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can cause them to sway, resonate, buckle or shear.

In the area of automotive design, wind tunnel research helps determine the best vehicle shapes in terms of the lowest drag coefficients. Lowering the aerodynamic drag on a vehicle improves its fuel economy. Doing so also allows a vehicle to attain higher top speeds without having to increase horsepower. Wind tunnel research also extends into nearly all forms of racing. In Olympic events, wind tunnel research is even applied to the design of bicycles, skiing gear and bobsleds.

Main Assemblies

First, locate a suitable furnace blower unit. I was lucky in that the unit I obtained was already wired with a two-speed switch and a variety of electrical wire taps that I could change to control the motor's speed. Many styles of furnace motors and blower styles exist.

In the tunnel that I feature in this article, the motor was mounted within the blower unit. For safety reasons, I recommend that you also use a style that has an internal motor, which helps keep students from getting caught in moving parts such as belts or pulleys. Also, that style makes it easier to construct protective shielding and screens to keep fingers away from moving fan blades. Finally, the overall appearance of the finished wind tunnel will have a more polished and professional quality.

Next, purchase a section of furnace duct that you can mount on the blower unit. The duct I selected did not match up to my unit at first, so I had to make flanges and a mounting surface to connect the duct to the blower unit.

Test Chamber

After you attach the duct to the motor/blower unit, you will need to cut away the test chamber. I used a Dremel tool with the appropriate cutting wheel to open a section that measured 24" x 7". I chose this size opening to ensure that students could test the drag on CO_2 cars. At this point, you need to consider what you will test in your tunnel and, thus, how large a test chamber you will need. Finally, remember that you must shield students from sharp edges. This is especially important regarding the opening you make for the test chamber. I cut the opening with interior flanges that were then neatly bent inward, which left a nice rounded surface to prevent students from getting cut.

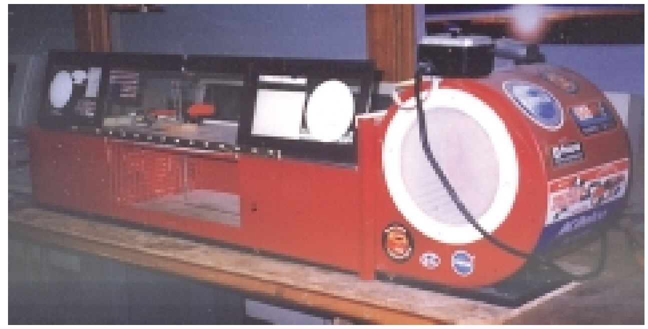

Photo 2—Another view of the wind tunnel, with the viewing window open

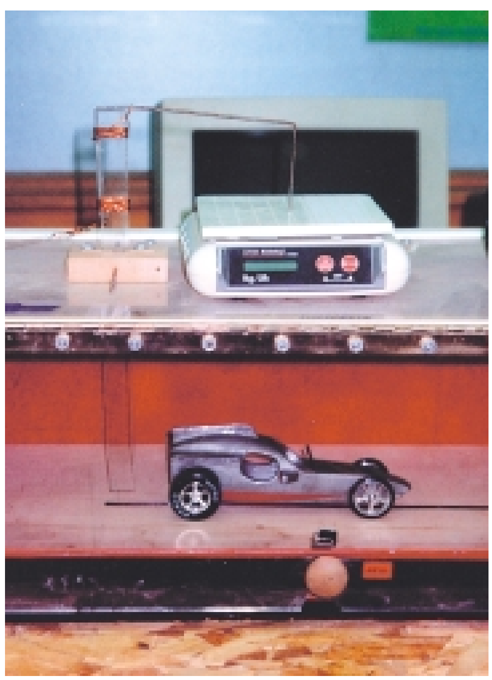

Photo 3—Closeup of the digital scale

Test Chamber Viewing Window

My test chamber viewing window measured 24" x 7". I sealed it with an oversized sheet of scrap Plexiglas that measured 44" x 8". I used a piano hinge to attach the plastic viewing window. The 30" piano hinge was somewhat expensive, but I decided that the ease of attaching the plastic and the overall durability that the hinge would provide made it well worth the cost. The weight of the Plexiglas helped to seal the test chamber to some degree.

At this point, I tried the wind tunnel for the first time. I noticed that even at a low motor speed the viewing window did not completely seal itself through its own mass. I realized that I would need to make a latch and perhaps a seal to prevent air loss but decided that I would address that problem later.

Creating a Scale for Measurement

Many teacher-built wind tunnels use a mechanical device, like

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a spring gauge or a needle and pointer, to measure drag. The teacher typically makes the scale. The chief improvement in my wind tunnel is the use of a digital scale. Digital scales are available from a variety of science and technology education suppliers. While they can be somewhat costly ($100 or more), you may be able to purchase one cheaply though an office supply store. One unit I found after I completed my wind tunnel—intended for measuring weight for postage—cost just $25!

The measurement device that I constructed was based on a lever that pivots in a block mounted on top of the test chamber. (See Photo 3 and Fig. 1.) I fashioned a coat hanger wire into a "U" shape and glued it to the plastic lever using cyanoacrylate glue (Super Glue) to tack it to the arm. I then glued it permanently in place with 15-minute epoxy.

I added a spring using 1/4" nuts, a bolt, a spring from an ink pen and a piece of angle iron. This assembly also mounts on the top of the test chamber. (Be sure to allow enough room for the measurement of test objects inside the chamber.)

Photo 4—A car in the wind tunnel. Note the lever behind the car, which is attached to the meter.

Measuring Wind Speed in the Chamber

Wind speed in industrial/scientific tunnels comes in at velocities at the subsonic, sonic, transonic, supersonic or even hypersonic levels! Thus, your tunnel will only be adequate for rough measurement of student-made models. (Anyone considering pursuing serious aerodynamic research may want to rent some time at a NASA test facility!)

You can obtain wind speed meters from a variety of sources, including scientific and technological supply catalogs. You may not need the ability to measure the velocity of the air in your tunnel if you plan to use it for rough measurements only. But, if you plan to also use it for other applications—such as measuring lift on airfoils or down force on automobiles—it would be good to be able to both control the air velocity within the test chamber and make accurate readings. Extension activities could then include charting and graphing aerospace concepts.

Sealing Leaks

The final step in constructing and testing your wind tunnel involves sealing air leaks. You can easily repair many with caulk. One major problem that I encountered was sealing the test chamber door. Whenever I turned on the wind tunnel, the door would blow open with a significant amount of air loss. I tried mounting a mechanical latch that I bought at a hardware store, but the latch still did not seal the door well enough. After much consideration, I settled on using a large supply of 1" rolled hobby magnets, placing the magnets around the plastic viewing window. The magnets proved sufficient to both seal the chamber and prevent air leaks.

Final Thoughts

Building a wind tunnel makes a great research and design project for either high school students or preservice technology education teachers. After using my wind tunnel for more than four years, I have been happy with its durability and operation for rough measurements. Yet, I have felt that there is still much room for improvement. I would consider the following ideas if I were to construct another wind tunnel.

In the wind tunnel that I constructed, the wind blows on the model and the model pushes on a lever to transmit the force of drag onto a digital scale. I might consider changing the placement of the lever to in front of the model to be tested. To create better airflow, you could shape the lever's acrylic plastic to make it more aerodynamic. The test model could then be placed in the tunnel and hooked behind the lever. This would help with aligning lightweight test objects and preventing bad measurement data due to alignment issues.

I would also recommend blowing some kind of smoke or fog over the model so that students could easily see and compare the turbulent air flow and/or the laminar air flow around a test object, but I have not yet found an easy way to do this. Finally, I would consider wiring into the tunnel some controls to better adjust the velocity of the air inside the test chamber.

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Internet Resources

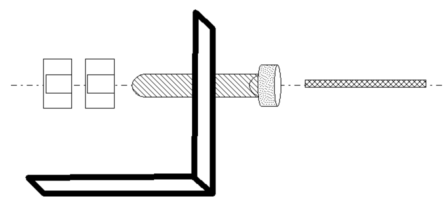
www.arc.nasa.gov/audience/foreducators.html
http://wind.tamu.edu
http://windvane.umd.edu
www.advancedtechnologiesinc.com
www.aircraftdesign.com/books.html
www.trimodels.com
www.worthey.net/windtunnels

Internet Sources of Blowers and Motors

www.electricmotorwarehouse.com/Furnace_Motors.htm
www.heatcoolparts.com/motorpage.html
www.keithspecialty.com/motors%20and%20acces.htm
www.nelsonmachinery.com/blowers.htm

Build a Wind Tunnel

Closeup of the measurement device



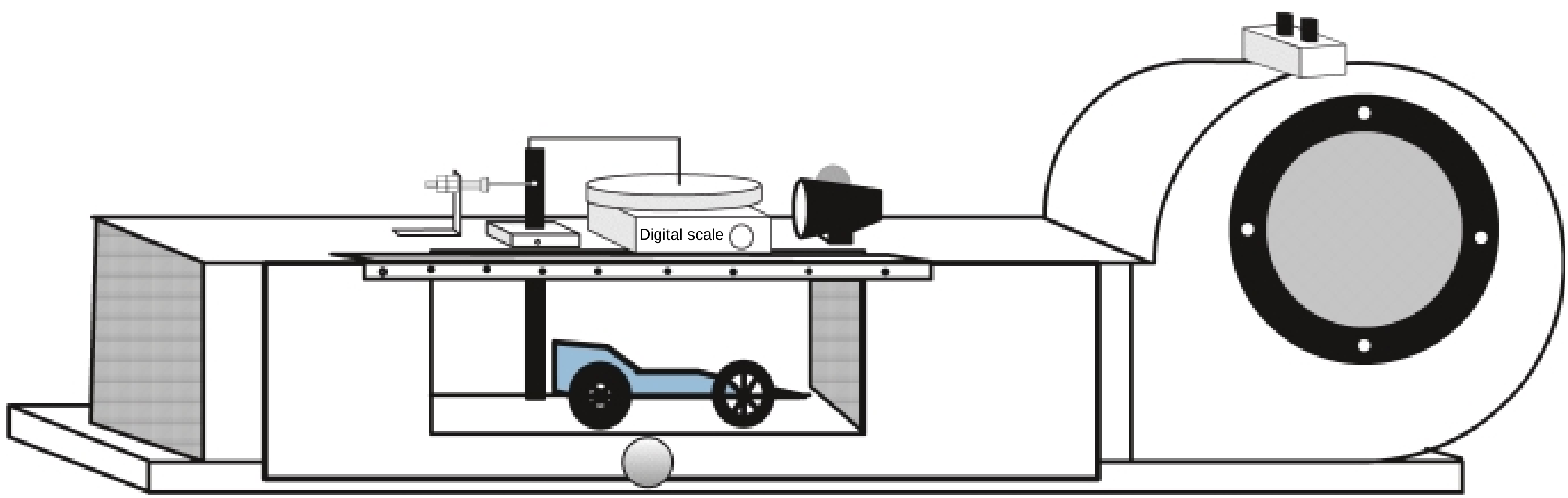


Fig. 1—Wind tunnel details

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Tools and Materials

- Furnace fan with internal motor
- 4' length of furnace box duct
- Digital scale (available through science supply catalogs, Pitsco, etc.)
- Wire coat hanger
- Wind speed gauge (available through science supply catalogs, Pitsco, etc.)
- 1-1/2" PVC pipe
- 30" piano hinge
- Wood door pull
- Rolled hobby magnet strips
- Sheet of clear acrylic plastic, 44" x 8"
- Acrylic plastic push arm, 1" x 14"
- Two pieces of screen door mesh
- Two plywood rings (make to fit)
- Plywood base (make to fit)
- Two plastic grates
- Can of spray primer
- Can of spray paint (your choice of color)
- 2 1/4" nuts
- 1 4" x 1/4" bolt
- 1 Angle
- Spring from a pen