The Benchtop Wind Tunnel

A Useful but Little-Known Tool for Science and Engineering

Introduction

We are all familiar with wind tunnels and have seen films or photos of their use in aircraft and spacecraft design as well as in automobile ads touting the aerodynamic features of this car or that. In more recent times, they have found new uses in the design of bridges to prevent resonance in high wind conditions and to aid in the design of modern super buildings to ensure that they survive hurricanes and typhoons. But there is a little known world of wind tunnels that has practical value in everyday engineering, academia, research and development, and even product design. This is the world of the benchtop wind tunnel.

These devices adhere to all of the general principles of wind tunnel design, such as controlled air flow, low turbulence, flow accuracy, and repeatability, but they use these properties for applications that are, literally, more down to earth. The simplest are used for the calibration of air flow measurement devices known as anemometers, while the most sophisticated are used for the same kind of aerodynamic studies as their giant counterparts, but on a miniature scale. Recently, totally new applications have emerged for the tabletop wind tunnel that have practical use in everyday engineering; analyzing the thermal characteristics of heat producing items such as circuit boards and electronic components, and measuring the properties of heat sinks, heat exchangers, and other cooling or heat transfer devices.

Wind Tunnel Elements

Benchtop wind tunnels are typically open-loop systems, which means that the air is drawn from and is expelled into the room, as opposed to the same air recirculating through a duct system or another closed path. Large or small, wind tunnels have certain key elements in common. Let's take a look at these. The test section or air chamber, which is often the smallest part of the device, is the main focus of the user. It usually has either a round or square cross-section and is where the test conditions exist and the measurements can be made. All the other elements of the wind tunnel are devoted to producing the controlled air flow needed for the test chamber. These include the fan or blower section to move the air, a combination of honeycombs, vanes, filters, and other devices to help reduce air turbulence and produce a laminar flow, and an area of varying duct cross-sections to shape the flow as it moves into the test chamber.

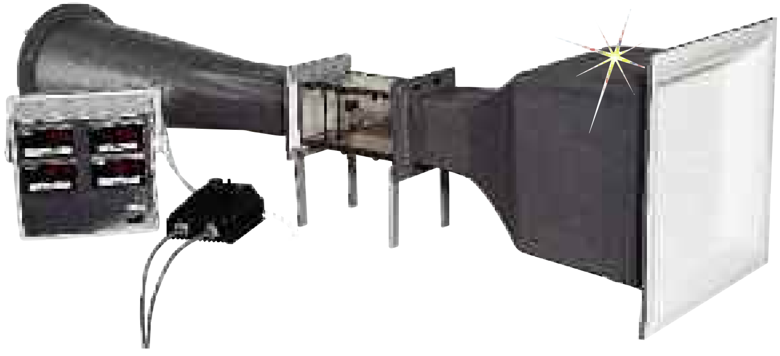

Figure 1 –Laboratory-Grade benchtop wind tunnel shown with control panel (Omega Engineering, Inc.)

Figure 1 shows a typical benchtop wind tunnel (Omega Engineering, Inc., Stamford, CT). The transparent test chamber can be seen in the center. A fan on the left pulls air into the square opening on the right where a fiberglass honeycomb filter produces a uniform stream that is then shaped by the duct leading to the air chamber. This unit can be used for either calibration or air flow studies.

Applications

Let's take a closer look at the common applications for benchtop wind tunnels mentioned earlier. The first and simplest is anemometer air flow calibration. Anemometers, which are devices to measure air velocity, are ubiquitous in many areas of science and engineering, as well as in certain trades. The two most common styles, each employing a different technology, are the vane type air velocity anemometer, in which a small fan spins in response to air flow, and the hot-wire anemometer, in which a resistive element cools as air passes over it. In industry, these devices are used for all kinds of air flow testing and adjustment. In addition to general workspace ventilation, they are used to monitor air velocity in spray booths, fume hoods, clean rooms and laminar flow workstations. They are also employed to determine flow through large filters and cooling or heating coils used for industrial processes. Within the scientific community, anemometers find widespread use in weather measurement and analysis, in environmental studies, and for research. Probably the most common use of all is in the installation and maintenance of HVAC systems, where an anemometer is essential for air balancing, flow measurements, and troubleshooting.

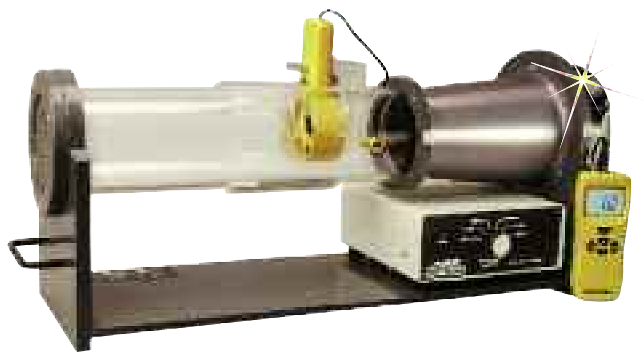

Figure 2 –Benchtop Calibration Wind Tunnel (Omega Engineering, Inc.)

A wind tunnel for calibrating anemometers is very easy to use and needs no special knowledge. The test chamber is usually configured to accept specific models, either vane type or hot-wire anemometers, and the air flow is pre-calibrated against an NIST standard. Simply mount the unit under test, select the air flow and read the output on the test unit. The unit in Figure 2 is controlled from the instrument panel shown. A multiposition switch selects the air flow rate.

For more general wind tunnel applications, a model like that shown in Figure 1 offers far more flexibility. This device can not only be used for laboratory calibration, but is also suitable for applications similar to those of its big brothers, such as aerodynamic studies using models. Typical uses include product design and development, R&D projects, and university laboratory experiments. The test chamber can accommodate custom mounting fixtures and instrumentation and includes the capability to measure temperature, humidity, and barometric pressure. Such laboratory-grade wind tunnels typically have a much wider range of flow rates than the much simpler calibration wind tunnels – 25 to 9000 fpm (feet per minute) vs. 500 to 3000 fpm. Additionally, the flow rates are continuously variable and not preset as they are in a calibration wind tunnel. To achieve the lowest flow rates, specially designed restrictive plates are used that cut down the air flow while maintaining the required high uniformity and low turbulence.

The latest application to emerge for these handy air flow devices is in everyday engineering design: thermal evaluation of electrical and electronic components. This includes active devices like circuit boards and powered components, and passive devices like heat sinks and heat exchangers.

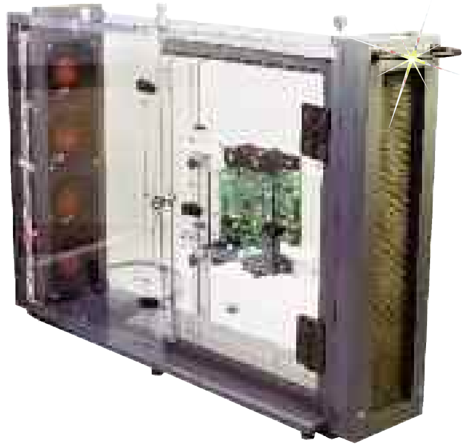

Figure 3 –Benchtop Thermal Evaluation Wind Tunnel (Omega Engineering, Inc.)

Physically, these devices are a radical departure from the more familiar designs used for air flow studies and calibration. As can be seen from the example on the left, in contrast to its traditional counterparts, the air chamber is the largest part of this unit. The fans on the left can be individually controlled and draw air through the right where a honeycomb filter suppresses turbulence and sets up a uniform flow. The unit under test is suspended in the air chamber on a universal mounting fixture that can be adjusted to accept a wide range of test objects. Several openings in the test chamber allow for instrumentation such as temperature sensors and anemometers. Air flow is continuously variable so that different test conditions can be established and temperature profile measurements made. This unit can be operated by a small control box or through a pc interface.

Conclusion

Wind tunnels are certainly not a common tool for most engineers; however, the little-known category of benchtop wind tunnels can offer great gains in test, measurement, and design effectiveness in the right applications. For those routinely using anemometers, a benchtop calibration wind tunnel is a practical way to bring calibration capability in-house. For those involved in research and advanced product development, a laboratory-grade unit can be a decisive data resource. For designers of circuit boards, heat-generating components, heat sinks, or other cooling devices, a thermal evaluation wind tunnel offers a brand new way to create safer, more reliable, and higher quality products. If you fit into any of these categories and had never heard of benchtop wind tunnels, welcome to a new path to productivity.

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