Industry Developments:

Versatile Laboratory Wind Tunnels

The world's largest wind tunnel is at NASA's Ames Research Center in California. Here, engineers tested the 50-ft diameter parachute design that would help bring the Curiosity rover safely to the Martian surface in August 2012. However, for the electronics thermal management industry, studies employing laboratory-sized tunnels are the norm. Advances, design and controls have increased their versatility and ease of use.

Large or small, all wind tunnels are basically alike. Their main compartment contains a central test section where objects with attached sensors are positioned or where air velocity sensors requiring calibration are lined up. Air streams through the tunnel and through the test section at a controlled rate, usually driven by a fan.

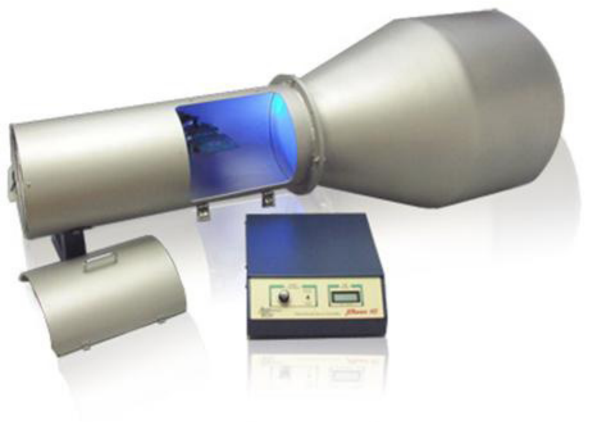

Figure 1: Servo Controlled Wind Tunnel and Control Console [1]

Wind tunnels used for studies in electronics thermal management can be found in many research labs and universities around the world. While performance varies among models and their operators, most laboratory wind tunnels share similar design components.

The most common characteristics of lab wind tunnels are a blade assembly, power supply, test chamber, control unit and a data acquisition system that interfaces with a PC. To achieve uniform and good quality flow in the test section, research quality wind tunnels include a settling chamber and contraction systems to smooth the airflow. A good quality wind tunnel should have a flow uniformity of 0.5-2%, a turbulence intensity of 0.5-2% and temperature uniformity of 0.1-0.5°C at the inlet of the test section.

In basic operation, air is drawn through an entry site into the test section by a variable speed fan. A properly designed tunnel will ensure laminar air flow through the test section. The test chamber is typically inside a clear-walled enclosure allowing clear observation of the test in progress. Many laboratory wind tunnels will fit on a bench top, while others, with larger test areas, are floor models.

Thermal Studies

Since the thermal resistance of air-cooled electronic devices depends strongly on air flow velocity, accurate measurement and control of flow speed is essential for accurate test results. With a device-under-test set into the test section, thermal resistance measurements can be accurately performed over a range of air flow speeds. A control console continuously displays the air flow speed in feet per minute. Air speed can be controlled manually or automatically from a PC-based thermal analyzer. More capable wind tunnels allow batch testing of heat sinks or other components. The airflow speed is automatically indexed to the next value in the test regimen after equilibrium is reached in the current test.

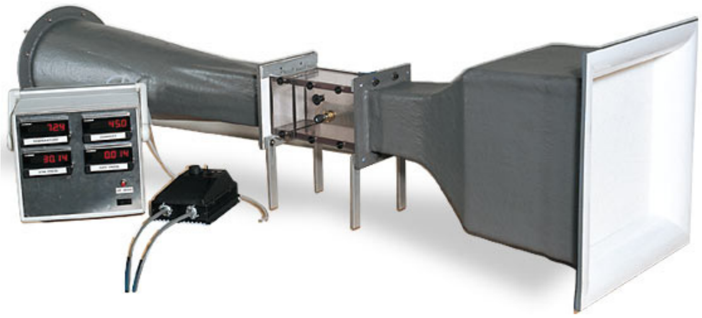

Figure 2: WT4401 Laboratory Grade Benchtop Wind Tunnel [2].

Omega's advanced wind tunnel is designed to give a highly uniform flow rate over a 6 inch (152 mm) test section. A powerful 12 amp motor with variable speed from 0 to 10,000 RPM is adjustable to give a particular flow rate using a motor control unit. The uniform flow rate is determined by monitoring a highly repeatable differential pressure sensor which has been calibrated to each individual wind tunnel as a system. Each wind tunnel is supplied with two restrictive plates for achieving optimum low flow rates. The established differential pressure measurements versus flow rates are listed from 25 to 9000 FPM. Calibration sheets are included, which makes calibrating different flow sensors simple.

The differential pressure measurement used to establish known flow rates will be affected by barometric pressure and temperature conditions during testing. Depending on the application, humidity may also be a factor. With these concerns in mind, Omega offers an enhanced wind tunnel package. It provides an environmental monitoring system that measures barometric pressure, room temperature, humidity and differential pressure. By monitoring room conditions, standard differential pressures can be converted to actual differential pressure readings to ensure accurate flow rates.

Closing the Loop

An open wind tunnel draws air from ambient and exits into ambient. There is no control on the temperature in this kind of wind tunnel, and it follows the ambient temperature. In a closed loop wind tunnel, the internal air circulates in the tunnel loop, separating it from outside ambient air. The temperature in this kind of wind tunnel can be controlled by a combination of heaters and heat exchangers. The air temperature can also be varied from sub-ambient to over 100°C.

Figure 3: Closed Loop Wind Tunnels, Like the CLWT-115™ from ATS, Offer More Control of Air Temperatures Within the Test Section [3].

The CLWT-115™ from Advanced Thermal Solutions, Inc. is a research quality closed loop wind tunnel that provides a convenient, accurate system for thermally characterizing PCBs and individual components at controlled temperatures from ambient to 85°C. The CLWT-115™ wind tunnel produces air flows up to 5 m/s (1000 ft/min). With customization, it can generate flows up to 50 m/s (10,000 ft/min) using orifice plates (available optionally). The clear Lexan test section lets the user view the test specimen and allows for flow visualization. Unlike open loop wind tunnels, the CLWT-115™ recirculates internal air. This allows the system heater to quickly warm the air to a specific temperature. The testing of boards and components in hot air is a requirement in some NEBS and other standards.

The precise controls and temperature range of the CLWT-115™ wind tunnel allows its use for testing heat sink performance and for calibrating air and temperature sensors. The complete wind tunnel fits on most lab benches and is powered from standard AC outlets. It has a smaller footprint than traditional, closed loop wind tunnels or environmental test chambers. The wind tunnel's test section can be accessed from the top door or sides for mounting and repositioning of boards, components and sensors. Internal rail guides provide an easy mechanism to install test specimens of different sizes (e.g., PCB, heat sink). Instrument ports are provided in the side walls of the test section for placing temperature and velocity sensors such as thermocouples, Pitot tubes and hotwire anemometers.

Going Supersonic

NASA engineers at the Glenn Research Center developed a downsized supersonic wind tunnel with a 15 x 15 x 71 cm test section. [4] This tunnel is typically used for instrument development and calibration of supersonic flows or fundamental studies of supersonic flow phenomena. Air enters a plenum-contraction section and travels into a nozzle assembly with fixed geometry nozzle sections that can rotate 90 degrees for each of Mach number changes. The Mach number ranges from 1.3 to 3.0. The tunnel offers 160 ports that allow ±15 pressure differential measurements. The supersonic wind tunnel has been used for simulation studies of aerodynamic shocks and laser-based shock sensing for in-flight and ground electronics. [5]

Conclusion

Developing new wind tunnels is a lengthy process and requires extensive knowledge and experience in the theory and construction. Choosing a wind tunnel for a lab or school also must factor in cost and space constraints. Larger wind tunnels require more space to have all the conditioning elements in place. A desk top wind tunnel will sacrifice some features, such as higher end flow quality, but most models are acceptable for practical engineering purposes.

References:

1. Analysis Tech (Analysistech.com)

2. Omega (Omega.com)

3. Advanced Thermal Solutions, Inc. (Qats.com)

4. NASA (https://Rt.grc.nasa.gov)

5. NASA/TM 2012-217439, Wind Tunnel Testing of a One-Dimensional Laser Beam Scanning and Laser Sheet Approach to Shock Sensing, March 2012.

Introducing the New Closed-Loop Wind Tunnel

CLWT-115™