Aerodynamic Wind Tunnel Testing for SmartWay Verification

What is wind tunnel testing?

A wind tunnel test uses a test chamber to evaluate air flow around an object and is often used for measuring the aerodynamic efficiency of vehicles and airplanes. In most wind tunnels, only a smaller scale model of an actual vehicle will fit inside the test area. The test vehicle model is mounted in the middle of the chamber and air is moved through the tunnel duct by a fan system. This simulates air flowing over a moving vehicle under various wind conditions. The test model is usually instrumented to measure wind forces, air pressure, vehicle speed, wind angles, and other airflow characteristics.

Testing at Auto Research Center's (ARC's) 1/8th scale wind tunnel using a model tractor and box trailer

To better match real-world conditions for vehicles, some wind tunnels simulate a moving floor (i.e., "rolling road" tunnel) under the vehicle model's rolling wheels. Further, most tunnels can also turn the truck models to simulate wind hitting the truck from different angles relative to a head-on wind.

What kind of measurements can I expect from wind tunnel testing?

In the wind tunnel, air forces pushing against the body of the vehicle model are measured and used to calculate the model's coefficient of drag (Cd). The lower the Cd, the lower the energy (e.g., fuel) needed to move the truck forward through air. In evaluating vehicle design changes (e.g. adding aerodynamic devices), the changes in drag forces are used to calculate fuel economy impacts.

The wind tunnel test simulates varying wind conditions by turning the tractor-trailer model to expose the sides to precise wind angles. A "wind-averaged Cd" value (Cdw) is an average aerodynamic drag calculated from a range of wind angles that help represent typical winds on the open road. In contrast, some other truck test methods are limited to low-wind conditions to improve repeatability.

For EPA SmartWay verified aerodynamic devices, the manufacturer must first conduct baseline runs (model vehicle without devices), followed by test runs (model vehicle with devices installed). The

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change in the wind-averaged drag (Cdw) is then multiplied by factors to project the vehicle's fuel usage at different speeds. SmartWay verification is based upon the projected fuel savings from the aerodynamic devices at an actual vehicle speed of 65 mph.

How do wind tunnel results relate to the real-world?

A properly conducted wind tunnel test can provide a good indication of the relative improvement (e.g., change in Cdw or potential fuel savings) of an aerodynamic device for a range of wind conditions at highway cruise (65 mph). To translate this result to in-fleet performance, a fleet can apply the wind tunnel result to its own driving (speed) profile.

Wind tunnel testing has relatively low test-to-test variability compared to other test methods. However, each wind tunnel will have unique characteristics (e.g., how it holds the model in place; how it simulates complex near-road airflow around a truck; other "boundary layer" interferences) that may influence how closely the results estimate real-world performance.

The most representative test results will come from closely simulating on-road conditions and using a truck model that is as realistic as possible. In addition, because wind tunnel testing is conducted on a scale model, certain devices are not suitable while others may perform differently from the real-world. EPA SmartWay works with aerodynamic manufacturers to ensure that suitable devices are properly tested in the wind tunnel for verification.

How do wind tunnel results compare to that of other tests?

Each test method for SmartWay verification has advantages and disadvantages relative to the others. Below are some considerations:

Track tests use real tractor-trailers so the complexities of an operating truck are built-in. This is also the only SmartWay test that directly measures fuel savings without using a factor to convert aerodynamic drag improvement to a projected fuel savings. However, operating full-sized trucks in an outdoor environment adds variability. This makes it important to limit factors that could increase variability (e.g., weather, engine response) by adhering rigorously to the test method and closely monitoring and documenting testing conditions.

Coastdown tests use real tractor-trailers and limit engine and drivetrain influences by disengaging them – to more directly isolate and measure air resistance. To minimize the variability resulting from external factors (e.g., changes in road grade, weather, vehicle set-up), it's important to follow the protocol conditions closely and to thoroughly monitor and document testing.

Wind tunnel tests provide excellent repeatability due to the greater control of the environmental factors. Test facilities can also apply simulated side winds to evaluate how an aerodynamic device may perform in on-road conditions. Because changes can be made to the trailer (or tractor) body relatively quickly, scale wind tunnels are often used for design work. However, it is critical to represent the tractor-trailer and device with as much realism and fidelity to detail as possible, in order to produce results that represent real-world performance. For some aerodynamic devices, it may not be possible to scale the representation down enough to fit onto a small truck model.

Computational fluid dynamics (CFD) tools provide excellent repeatability by simulating on-road wind conditions (like the wind tunnel) and generate animated visual simulations of air flow and wind interactions around a truck. These animated visualizations can illustrate how a device works to reduce air resistance, instead of simply calculating a projected fuel savings. CFD tools can be limited in the amount of tractor-trailer and environmental complexity that can be represented in the computer model, so it is important to understand the limitations of what is and is not included in a CFD computer simulation.

In general, all these methods produce results that simulate highway cruise conditions and must be appropriately interpreted when applying to a fleet's unique driving profile. The testing organization and/or SmartWay can help fleets understand how their on-road fuel savings may differ.

For more information: www.epa.gov/smartway/forpartners/technology.htm or Tech_Center@epa.gov.