How to use pitot tubes

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A Pitot tube is a simple and inexpensive instrument that can help you better understand the aero of your racecar. A **Pitot**-static tube is a common sight on aircraft and high-end racecars. This article explains how **Pitot** tubes work and how you can use them to extract speed from a car.

A **Pitot**-static tube comprises an inverted-L shaped tube that is pointed in the direction of the car's travel. There is an orifice at the tip and a ring of holes in the horizontal section of the tube. These feed two ports; the first subject to total pressure due to the car moving through the air and the second subject to the static air pressure. The difference between the two is the dynamic pressure. The **Pitot**-static tube's ports are connected to a differential pressure sensor which measures the difference in pressure between the two ports and gives an electrical output proportional to this difference. Typically this will be in a -2 to +2psi (-14 to +14KPa) range.

The **Pitot** tube should be mounted in an area of relatively undisturbed airflow and, as mentioned, pointing in the direction of the car's travel. The horizontal section of the tube should be parallel to the ground.

Fig 1



For data analysis a reference of static air pressure and temperature is also important. This can be obtained from a weather station in the pits. Some circuits provide weather data on their TV feeds and even some wristwatches have a barometric pressure display capability. It can be assumed that around the small area of a race circuit, static pressure is constant. Advanced weather station systems will log the conditions over a session and insert it into the outing data downloaded from the car allowing very accurate analysis of car performance versus weather data to be performed in the data analysis package.

The data from the **Pitot** tube can be used in a variety of ways. A first step is to use the dynamic pressure to calculate the car's air speed so the effect of wind direction can be explored. The following equation calculates airspeed from dynamic pressure:

airspeed(m.s-1)=2 2.p(kg.m-3) · Pdynamic(Pa)

This equation makes use of air density, ρ , an estimation of which can be calculated using the ideal gas law using the temperature and pressure measurements from the weather station1.

Once air speed has been calculated it is a simple step to calculate headwind from the difference between it and the car speed measured from the wheels or GPS.

headwind(m.s-1)=airspeed(m.s-1)-carspeed(m.s-1)

If headwind is positive, the car is heading into the wind. If the data analysis package supports it, plot headwind around a map display so its affect around the circuit can be shown. In the screenshot calculated air speed and headwind are plotted against car speed on a time/distance chart.

Headwind is plotted around the circuit; the plot is red if the wind is working against the car and green if it is helping it. It can be seen that down the main straight the colour is predominantly red meaning the car is heading into a headwind. This will reduce top speed due to drag but aid downforce into the braking area. In this case, it may be possible to reduce lap time by taking some wing off to improve top speed at the cost of some braking potential. The effects of headwind can explain why the car may be making more or less downforce than is predicted and analysis of this nature can be used to explore the reasons why.

Away from the analysis of the effects of the prevailing weather conditions on a car during a race weekend, a **Pitot** tube can show its value during testing too. By using a series of techniques such as straight-line and coast down testing in controlled conditions, the dynamic pressure can be used to calculate estimated downforce and aero balance. It's even possible to build an aero map of the car.