Lessons from the track – tire temperature can tell you a great deal

Application Note

Just as you count on high quality tools to do your job effectively, smart race car teams depend on precise temperature tools to provide a winning edge. Fluke delivers robust and versatile temperature tools that adapt to their most demanding needs.

Whether hitting hairpin turns at more than 50 mph, or scorching the asphalt at speeds reaching 200 mph, a NASCAR driver depends on his race car to be in optimal condition, and that includes his tires. A severely worn tire weakened from excess heat that exposes tire cords, or a cold tire that is not "sticky" enough could slow the car or endanger the driver.

The tires on a race car are critical because they keep the car on the track and translate the driver's steering, brake and accelerator inputs into motion. The driver continually tests the limits of tire adhesion, especially in road course events. The tires ultimately determine how fast the driver can accelerate, corner or brake.

Racing tires are substantially different from those on a passenger car. The three biggest differences are:

1. Race car tires are much wider – up to12 inches wide in the front and 16 inches wide in the rear, whereas the typical passenger car tire is seven to nine inches wide.
2. Racing tires may be completely smooth to maximize the amount of rubber touching the track surface.
3. The rubber on the face of the tires is extremely soft. It is more like a soft rubber eraser than anything else, and very unlike the hard rubber found in passenger car tires.

Between the size of the contact patch of a racing tire and the softness of the rubber, the tires have incredible adhesion. The severe driving conditions cause racing tires to deteriorate very quickly compared to those on passenger cars. Tires on a passenger car are designed to last 40,000 to 60,000 miles, whereas race car tires may last only 100 or 200 miles!

What about tire temperature?

Racing tires get very hot due to tread flex and friction generated by rotational speed and by cornering and braking. The higher the load and the higher the speed, the hotter the tire will get. But that heat will not be distributed evenly. One tire may run hotter than the others, or one area of the contact patch may be hotter than another. If you can accurately measure tire temperatures and observe how those readings are distributed across the tire, you can adjust tire pressures and suspension to achieve improved performance.

When it comes to determining the temperature of race car tires, it is vital that the driver use the most robust and reliable thermometers on the market.

Infrared thermometers

There are two tools available for measuring temperatures on race car tires. One is an infrared thermometer. Infrared thermometers run on thermal, or infrared energy, which is light with a long wavelength that makes it invisible to the human eye. It is the part of the electromagnetic spectrum that is perceived as heat. Unlike visible light, in the infrared world, everything with a temperature above absolute zero emits heat, even very cold objects like ice. The higher the object's temperature, the greater the IR radiation emitted. Infrared allows us to see what our eyes cannot.

When taking race tire temperatures it is important to keep the tires as close to operating temperature as possible. Therefore, you must run two to three hot laps to heat the tires and get into the pits quickly. Temperature readings are taken as soon as possible, since the tread surface is cooling rapidly.

Because of their versatility, infrared thermometers are also used to detect sources of heat that affect the driver, locate dead engine cylinders, or read the temperature of bearings, brakes or the track. *(See sidebar.)*

Contact thermometers

A second method calls for using contact thermometers. Contact thermometers with a piercing style thermocouple probe are significantly more reliable than IR because they are more accurate. When determining the temperature of race tires, you gauge the internal temperature of the tire tread, not the tread surface.

The internal tread temperatures do not fall as rapidly as the surface temperatures, so by measuring temperatures 1/8 of an inch into the tread, you have a little more time to make an accurate measurement of a hot tire.

Using an infrared thermometer, you will get a surface reading that may be 10-40 degrees cooler than temperatures taken with a probe type thermocouple.

Three readings are taken on each tire: inner tread, center tread and outer tread. Inner and outer readings are taken one inch from the tread shoulder. Write down the readings for evaluation. Check with your tire manufacturer to find the recommended operating temperature for your tires. A typical operating range for a DOT-R tire is 180 ˚F to 200 ˚F with a hot pressure of 37 to 43 psi. You want to see no more than 20 degrees difference in temperatures across the tread, with the inside being slightly hotter than the outside.

Tire temperatures are also useful in fine-tuning the suspension geometry. Tire temperatures will tell you what part of the tire is contacting the track and how it

Five great uses for IR thermometers in your garage

1. **Brake and suspension system**

   Brakes/sealed wheel bearings: Diagnose a dragging brake caliper, binding brake shoes and rotor/drum for uneven braking.

   Tire temperatures: After driving a vehicle at highway speeds, measure the surface temperature of the tires. A tire with a much higher temperature may be under-inflated or require balancing or alignment.

2. **Climate control**

   Heaters/AC vents: Check heating and cooling systems output.

   Air conditioning system: Check the temperature of the high-side and low-side lines for correct pressures. The higher the pressure, the higher the temperature.

3. **Cooling system diagnostics**

   Radiators: Scan across the radiator or heater core surfaces to find core restrictions or blockage.

   Thermostats: Measure the thermostat temperature at the thermostat housing. Monitor this temperature to determine when, and at what temperature, the thermostat is opening. Be aware that the actual coolant temperature may be higher due to dissipation.

   Coolant sensors: Measure coolant temperature sensors and manifold air temperature sensors to determine if they are operating within the correct tolerance. You can compare the temperature reading to the electrical readings by using a multimeter.

4. **Drive train troubleshooting**

   Engine misfire detection: Monitor the exhaust manifold runner temperatures to detect a misfire condition. A cold indication may indicate a lean air/fuel ratio or ignition malfunction. If the engine is fuel injected, compare the injector coil temperatures to find the cooler one.

   Catalytic converters: Run the engine until it is warm and stabilized. Then shut off the engine and disconnect a spark plug wire on one bank of cylinders. Restart the engine and block the throttle to maintain 1000 RPMs with the one cylinder not firing. Measure the inlet temperature of the converter and compare it to the outlet temperature. You should see a differential of 50 degrees F or more if the converter is working properly. If there is less than 50 degrees difference in temperature, the converter needs replacing.

   Before replacing a converter, determine why it failed. A very high mileage vehicle may mean the converter expired. For a low mileage car, perform a thorough check to determine the cause. For normal engines with a misfiring cylinder at 1000 RPMs, you can expect that the temperatures observed will be 600 to 900 degrees F.

   Dry bearings or U joints: The strength of infrared thermometers is their ability to monitor and measure rotating components. A dry joint will run hotter than one with sufficient lubrication.

   Turbo charger: A turbo charger runs at extremely high RPMs, yet it must operate reliably for as long as the engine. The pressure and return oil system are critical for extended life. So it is very important to measure the temperature along this path to identify substantial changes that could mean a restriction or contamination.

5. **Paint and body**

   Paint: To adhere correctly to the surface of a vehicle, paint must be applied at specific ambient and surface temperatures. Surface body temperature also affects body putty compounds.

is working. Ideally, the entire tire tread surface should be in contact with the track and working as close to equal as possible–an easy task if we traveled in straight lines, as there would be no lateral forces applied to the tire.

In reality, you turn left and right and apply lateral forces to the tires that change the contact patch. This is why suspension systems have adjustable camber to compensate for the lateral forces applied to the tires in a corner.

Use the table below as a general guideline to interpret readings and make adjustments to the car:

What about tire pressure?

This is a common question heard at the track. Unfortunately, the answer is different for every suspension, tire, track, and ambient temperature combination. Tire pressures should be taken when the tires are hot using a precision measurement tool like the Fluke PV350 Pressure/Vacuum Transducer–accurate to a tenth of a pound–and a digital multimeter.

Start with a cold tire pressure that does not exceed the manufacturer's marking on the sidewall. Tire pressures will rise as the tire temperature increases. How much depends on how hard the car is worked, the suspension setup, track surface, etc. Check the pressures at the end of a session as you are making your tire temperature measurements. Adjust the pressures per the table below. Once the tires have cooled, recheck and record the cold pressures. They may be different for each tire. Now you have a good starting point for cold pressures.

Conduct and evaluate temperature readings frequently as different tracks, changes in ambient and track temperature, tire wear, and fuel level all affect ideal settings. Adjustments in pursuit of peak performance is a never-ending task.

Symptom	Cause
Center hotter than edges	Tire pressure too high. Reduce 1 psi for each 5˚ F delta.
Edges hotter than center	Tire pressure too low. Add 1 psi for each 5˚ F delta.
Inner edge hotter than outer	Too much negative camber.
Outer edge hotter than inner	Not enough negative camber or too much toe-in.
Tire below ideal temperature range	Tire pressure too high, tire too wide, or springs/sway bars too soft at that axle.
Tire above ideal temperature range	Tire pressure too low, tire too narrow, or springs/sway bars too stiff at that axle.
Front tires hotter than rear	Car is under steering (pushing). Too much front spring/sway bar, not enough rear spring/sway bar, front pressure too low, rear pressure too high, front tires too narrow, rear tires too wide.
Rear tires hotter than front	Car is over steering (loose). Too much rear spring/sway bar, not enough front spring/sway bar, rear pressure too low, front pressure too high, rear tires too narrow, front tires too wide.

Note that some symptoms have multiple causes, so one or more remedies may apply. Making one change at a time is advisable in order to evaluate the impact of the change.

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