Air Density & Fuel Mixture Tuning

Why air density should concern a tuner:

For maximum engine performance you need the correct air to fuel ratio, we all know this! Unfortunately it is often overlooked the effect that temperature, pressure and humidity have in determining the amount of oxygen available in the air, therefore the amount of fuel needed to maintain our target mixture.

Most have us have noticed the change in performance with a cold morning race or experienced the negative effects high altitude on our engines.

These influences are well understood for dyno testing and most quality software packages (like DTec's 'DYNertia2') allow for atmospheric correction of their power readings to compensate for changes in power output. Less oxygen = lower potential power, we can't prevent this; however we can reduce the impact.

Races are not run on a dyno! We must consider that the change in available oxygen will require us to change our fuel quantity if we are to prevent the mixture from being too lean or rich. The following article will discuss the effect of changing weather conditions and offer a guide as to what we need to do to correct our engine tune.

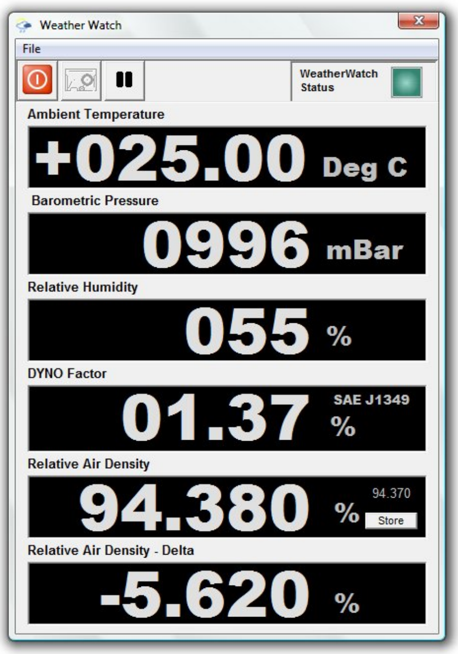
Effects of weather on air density:

Air density is the mass of air in a given volume. It is dependent on temperature, pressure and humidity. Lower density means less oxygen available for combustion.

Temperature-
Higher temperatures reduce air density and the amount of available oxygen. Hotter days require smaller jetting.

Pressure-
Lower air pressure (such as at higher altitudes) reduces air density and available oxygen. Altitude is a major contributor and every 1000ft you ascend there is a drop of close to 4% in density. Weather systems also have an effect and pressure can change very quickly during the day, particularly as a storm front approaches. Lower pressure requires smaller jetting.

Humidity-
Moist air has is actually less dense (just trust me on this one). A certain volume of air will contain a certain number of molecules (based on the 'ideal gas law') and it just happens that water molecules are relatively light compared to Nitrogen and Oxygen (H20 vs O2 and N2), therefore the more moisture the lower the density! Higher humidity requires smaller jetting.



Any of these variables can have a big effect (particularly temperature and pressure) but it's when you combine the influences that knowing air density becomes a truly significant factor in extracting maximum engine performance.

Calculating air density:

Don't do it! It's a lot easier to use a commercial air density meters or a more sophisticated device such as DTec's 'Weather Watch' to work with density or better still Relative Air Density (RAD).

If you choose to calculate densities based on individual atmospheric measurements (from precision wet/dry bulb thermometers, barometers or altitude data) then prepare to use lots of maths and psychrometric 'look up' tables. You will be dealing with terms such as vapour pressure, saturation vapour pressure, dry air pressure, dewpoint etc etc. If you truly wish to punish yourself then please see the DTec.net.au 'link' page for references to an excellent source of information.

Relative Air Density (RAD):

To allow us to get easy tuning information from air density data it is better to compare our value to a standard set of conditions, this is based on the international standard of 0 meters altitude, 15ºC, 1013.25mb pressure and 0% relative humidity.

So what we end up with is a simple comparison relative to a standard. If RAD goes up 3% it means 3% more density, if it goes down 3% it's 3% less dense (and therefore 3% less fuel required).

When you have our engine tuned correctly you simply note down the RAD reading. When racing under different conditions you note the new RAD reading, the difference in percentage is the difference in fuelling required i.e. if RAD is now 5% higher we need to set a 5% increase in fuel.

Jetting carburettors based on RAD:

A change in RAD requires a proportionate change in jetting. The only catch here is the way jets are sized- with RAD it's easy now to know if we need larger or smaller jets and by what percentage we need to alter the fuel flow, but how does a percentage in flow relate to jet sizes?
Unfortunately there is no standard method of numbering carburettor jets; different manufacturers have their own ideas.

Generally jet numbers can signify-

- Diameter e.g. 120 (1.20mm) also could represent thousands of an inch or be in wire gauge drill sizes.
- Area of the orifice.
- Flow in certain units at a particular test pressure.
- Just an arbitrary number the manufacturer assigns.

If jets are sized in flow then it's particularly easy e.g. if you needed an increase of 6% fuel and you had 200 jets then 6% larger would be 212 as the choice (200 x 1.06).

If jets are sized by diameter then we need to calculate the orifice area and use this to approximate the practical flow change. The following formula is simplified from the fact that Area=3.142 x radius^2.

New jet diameter = $\sqrt{}$ (Old jet diameter^2 x required flow factor). Flow factor is e.g. 4%=1.04, -7%=0.93 etc.

This jet 'area' tuning concept has been used for decades successfully. In reality however, there are many things that affect the flow through a jet, such as pressure differential, fuel viscosity, orifice diameter, entry shape, exit shape (coefficient of discharge), wall finish and length. The fuel discharge curve through a jet is easily upset by drilling or deposit build up.
If your estimated jetting change falls between available sizes then always err on the rich side and if a trend can be seen when observing the RAD over time then it may pay to anticipate the changing conditions.

Some re-testing after jetting with RAD will soon allow you to fine tune the approach for your fuel system. There is no substitute for using a wide-band air fuel ratio meter to confirm or trim the new settings if appropriate. This can sometimes indicate the need to reduce the jet size slightly from that calculated.

Observation of individual data is also useful for tuning. For example air temperature can play a big part in the tendency for detonation and could be useful for 'tweaking' the ignition timing.

Tools for measuring, calculating and tracking RAD changes:

Many air density tools don't account for humidity; this is due to the difficulty in measuring and calculating its effect on density.

Although humidity usually lies in a fairly narrow range and has less effect on density than temperature and pressure it wouldn't be trying to tune 'spot on' if we ignored it. 'Weather Watch' calculates what is sometimes known as 'corrected RAD', this accounts for humidity to achieve the highest accuracy.

Whatever equipment you choose you should consider the following-

- Accurate and able to account for humidity.
- Simple and fast to use so you instantly see RAD without looking up tables and calculating.
- Portable, rugged and value for money.
- Allow trends to be observed so you can track and anticipate changes. DTec's 'Weather Watch' can freeze the current RAD reading as a reference for changes.
- Display the weather data and not just the RAD value.
- Record to file so you can save with your race notes for future reference. You could graph this in 'Excel' to see how all the weather data changed throughout the day.
- It's also nice to see the power correction factor displayed, this gives an idea of the engines power potential under current conditions if the tuning can be optimised.

Summary:

An understanding of air density and its effects allows us to optimise our engine to maximise our performance. It's all very simple as long as we choose the appropriate equipment; we want to win races, not be in the pits playing weather man and physicist.

Foot note: density plays a big part in aerodynamics (just ask pilots) so the effects on your aero package and drag vs. down force might be worth tracking