AIR DENSITY: PRESSURE & TEMPERATURE EFFECT

by Robert Szabo

We run our drag race engines on the oxygen in the air. The air is only 23% oxygen by weight, so we have to run a lot of air to get an ample supply of oxygen to burn with our fuel. We run our gasoline engines at about 12 parts of air to one part of gasoline. We run our methanol engines at about five parts of air to one part of methanol for normally aspirated engines and about four parts of air to one part of methanol for supercharged engines. We run our Nitro engines at a little over one part of air to one part of nitro. With each of these fuels, we have launch enrichment and high speed lean out in some cases.

Each of our engines runs best on a specific ratio of air to fuel. In fact, it is a specific ratio of oxygen and fuel. Unfortunately the amount of oxygen in the air varies with the air density. Standard air is 100% air density. It occurs at sea level, 60 deg. F. (motor sports temperature standard), barometer of 29.92 inches of mercury and no humidity. A new "closet ghost" into that tuning task is smog. While the science of the effect of smog on race engine air is still unreported, I believe it is a growing concern. I have seen lost racecar performance on smoggy days with no other explanation. The air density rating for standard air would be with the absence of smog.

Unfortunately, we race in conditions that change the air from the 100% density value. We often race in hotter weather and that reduces the air density. We often race at racetracks that are above sea level and that reduces the air pressure. We also race in humid air and, of course, smog from time to time. All of these reduce the air density. Racers call that bad air. In a similar manner, cool weather or high barometric pressure increases the air density. Racers call that good air.

NEW CARS DO IT AUTOMATICALLY: In recent highway vehicles with electronic fuel injection, most are equipped with sensors in the exhaust. They read the amount of oxygen in the exhaust. Presence of too much oxygen indicates a lean condition. In this case, the vehicle computer richens the fuel to correct for this condition. Presence of too little oxygen indicates a rich condition. In this case, the vehicle computer leans the fuel to correct for this condition. As the vehicle is driven in different weather conditions and altitudes, the fuel system controls for the vehicle automatically compensate. The vehicle air to fuel ratio is continually adjusted for the best result in the exhaust. It automatically compensates for changes in air density. This goes on with little conscious awareness of the driver.

DRAG RACE VEHICLES OPEN LOOP: IHRA drag racing vehicles with carburetors or mechanical fuel injection do not have provisions for this automatic compensation. Also, crate motors with electronic fuel injection usually do not have provisions. As a result, the tuner uses weather and altitude information to determine fuel system adjustments. The tuner richens the fuel for good air and leans the fuel for bad air. The amount of fuel adjustment is a tuner skill acquired from experience and cleverness. Weather conditions for good or bad air are tracked with information from local weather reports, Internet weather information or the racer's portable weather station.

DRAG RACE TUNING FOR MAX: Two methods of compensation for air density are done. One is to adjust the engine for best power for the changing weather conditions. This would be common in open elapse time classes where there is no breakout. Examples are Top Fuel, Alcohol Funny Car, Pro Modified, and Pro Stock. In these classes, the performance will vary for good and bad air. The racers adjust for that. However, everyone in the class has a boost or handicap from the air.

DRAG RACE TUNING FOR REPEATABILITY: The other method is often used for the bracket classes with a target breakout elapse time. It is to determine from testing the effect on performance from good air or bad air. Then the racecar is adjusted to compensate for that effect from air density to reproduce a bracket elapse time target. The car is turned down in some manner for good air that would otherwise increase the power and performance. It is turned up in some manner for bad air that would otherwise decrease the power and performance. One common method is to change the shift point. It is raised for bad air to recover performance. It is lowered for good air to retard performance back to a target. Some race tuners change a throttle stop, the spark advance, or blower overdrive in blown applications. In any of the later, the intent is to compensate for air density changes where a specific elapse time target is needed.

DRAG RACE RECORD KEEPING FOR PREDICTING: In some classes, such as Top Sportsman or Top Dragster with an elapse time dial-in, many competitors do not change anything. They simply use experience or records from previous similar air density conditions to predict an elapse time. Then they dial that elapse time as the target. They adjust a faster elapse time dial-in for good air and a slower elapse time dial-in for bad air.

MEASUREMENT: AIR DENSITY GAGE: One simple method of determination of air density is to use a calibrated air density gage. This gage is equipped with a mechanism that responds to pressure and temperature changes. It produces an air density reading from typically 60% to 110% depending on the air pressure and temperature. Tuners use the reading from the gage for the previously mentioned tuning routines.

RECALIBRATE! Often tuners use that old air density gage that they bought 20 years ago without recalibration. In the long term, the readings will change. They can also change if it is dropped. In fact, vibrations from storage in the trailer on a long tow may throw it out of calibration. Several of the fuel system suppliers who advertise in DRM can supply an air density gage as well as recalibration. It is one tool you may want to carry in your "luxury" tow vehicle, on a soft pillow, or wrapped in a large towel on a seat. Air density gages do not provide information about the effect of humidity or smog.

WEATHER STATION: Another method of determination of air density is to use barometer and temperature values. They can be obtained from racer's instrumentation and more recently from hourly weather predictions from the Internet. With some simple math, those values can be used to determine air density also.

CALCULATION -- PRESSURE & TEMPERATURE EFFECT: The calculation for air density from barometer and temperature data is as follows:
1) First determine the barometric pressure in inches of mercury.
2) This has to be an uncorrected value. Unfortunately most local weather reports give barometric pressure in corrected values. These are adjusted for the altitude of the weather station. A reading of 30.05 inches of mercury from the local weather information center is an example of a corrected barometric pressure. Norwalk Raceway altitude is about 700 feet above sea level. The correction for that altitude is about - 0.7 inches of mercury. Therefore the uncorrected barometric pressure for Norwalk on a day with a local weather report of 30.05 inches of mercury is 30.05 – 0.7 = 29.35 inches of mercury. The corrected barometer is above the standard that would be thought of as an increase in performance. However, the uncorrected barometer is below the standard that actually decreases performance.

Altitude correction charts are available from Internet sources as well as some weather reporting services. Uncorrected barometric pressure values are available from some sources as well, although most barometer readings are corrected. Care is needed in sorting out the difference. According to Kinsler Fuel Injection, a rule of thumb is a reduction of one inch of mercury for every 1,000 feet of elevation.
3) Next, determine the temperature in deg. F.
4) Next, convert the temperature to absolute. That is done by adding 459.67 to the value.
5) Do the following calculation: Air density % = 1,736.86 x uncorrected barometer / absolute temperature

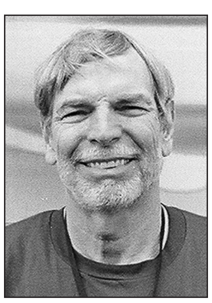
CALCULATION EXAMPLE -- PRESSURE & TEMPERATURE EFFECT:
(1) Assume a local barometer reading at Norwalk is 30.05
(2) Determine an uncorrected value. Either find that value from a source that has uncorrected barometric pressure in inches of mercury or convert the value from a correction table or chart. The correction for 700 feet elevation is approximately - 0.7 inches or mercury. The uncorrected value is: 30.05 - 0.7 = 29.35
(3) Assume a temperature of 90 deg. F
(4) Convert to absolute: 90 deg. F + 459.67 = 549.67 deg. Absolute
(5) Air density % = 1,736.86 x 29.35 / 549.67 = 92.7%

SUMMARY: You have just done a computation of the amount of air available at Norwalk (or anywhere else at 700 toot elevation) on a 90 degree F. day with a local weather report barometer of 30.05. All engines will be running on 92.7% air. Most with have some level of performance reduction as a result. It will not be that same percentage amount, but in many setups, it will be a performance change that is at least proportional to the air density change -- small air density change, small performance change -- big air density change, big performance change. Some supercharger engines can be compensated for air density change with blower overdrive adjustment, however, most normally aspirated engine power levels cannot be compensated. Again, all are in "the same boat" however.
Without a good source of uncorrected barometric values, the air density gage is an easier alternative. This calculation also does not show the effect of humidity or smog. They have less effect on air density, and the effect is complex. That discussion will be in a future tech article.

TUNING CALCULATORS: Several suppliers provide tuning calculators with provisions for pressure and temperature compensation. Supplier examples are Summit, Jeg's, Computeck, Corsa, and #1 Stop Products. Watch the DRM ads, DRM Yellow Pages and IHRA.com ads for sources and features.•

REFERENCES FOR THIS ARTICLE:
Kinsler Fuel Injection Catalog, Kinsler Fuel Injection Inc., Troy, MI (248) 362-1145
http://www.kinsler.com supplier for complete fuel injection services: products, repair, setup, tuner parts, and technical support

Weather Tech, Patrick Hale, Racing Systems Analysis, Phoenix, AZ (602) 992-2586
http://www.QUARTERjr.com supplier for drag racing software such as Quarter Jr., Engine Jr., and Clutch Pro; and race engineering consulting



About the Author

Bob Szabo is writer and owner / driver of a blown alcohol drag racecar. The air density % presented here is a value used in his technical book: "Fuel Injection Racing Secrets." Air density % will be covered in further detail in the author's next book on methanol racing fuel that is a few months away. Check the DRM Yellow Pages for Szabo Publishing or look on the Internet at http://www.racecarbook.com or call (707) 446 2917. If you have any comments about this article or any previous articles by the author, feel free to e-mail directly to the author at bob@racecarbook.com or to the DRM staff: pamela-marchyshyn@livenation.com or michaelperry@livenation.com