TECH STOP

AIR DENSITY WITH HUMIDITY

by Robert Szabo

BACKGROUND: In our previous article about the effect of air pressure & temperature on air density, an example was shown for Norwalk at about 700 feet elevation, 90 deg. F. day, with a local barometer of 30.05. An air density of 92.7% was the result for those conditions. This would be for dry air. Unfortunately, dry air is not the case anywhere that IHRA Drag Racing is done.

The engine intake draws in air from either (1) the vacuum from a piston opening a cylinder volume or (2) the lobes in a supercharger opening a cavity that causes a vacuum. In either case, the surrounding air fills the vacuum. Humidity is water vapor suspended in the air. Humidity takes some of the space normally occupied by air. That displacement of air is a displacement of oxygen in the air needed for combustion.

TEMPERATURE & PRESSURES: Warm air can hold a lot more humidity. A temperature of 100 deg. F. can hold almost two inches of mercury of water vapor pressure. That would be 100% relative humidity. Cooler air can only hold a fraction of that amount. For example, a temperature of 50 deg. F. can only hold about 0.36 inches of mercury of water vapor pressure. That would be 100% relative humidity at that temperature. Local weather information usually includes the relative humidity. It is in percentage of maximum for that temperature. Our example from the previous DRM article for air density was without consideration of water vapor pressure. The calculation was:

(5) Air density % = 1,736.86 x uncorrected barometer / absolute temperature

Air density % = 1,736.86 x 29.35 / 549.67 = 92.7%

HUMIDITY: The determination for the value of water vapor pressure from the relative humidity is a bit complex to determine. It is dependent on the temperature and the amount of water vapor. Now assume a relative humidity of 50% reported from the Norwalk Weather Center for this 90 deg. F. day. A summary of approximate values of water vapor pressure is shown for 50% relative humidity.

Temp. Deg. F	Vapor Pressure Inches Mercury
100º	0.96”
90º	0.71”
80º	0.52”

For 50% humidity on a 90 deg. F day, the water vapor pressure is about 0.71 inches of mercury. The calculation for air density % with humidity is:

$$(6)\quad \text{Air density \%} = 1{,}736.86 \times \frac{\text{uncorrected barometer} - \text{water vapor pressure}}{\text{absolute temperature}}$$

$$\text{Air density \%} = 1{,}736.86 \times \frac{29.35 - 0.71}{549.67} = 90.5\%$$

Humidity of 50% at 90 deg. F. reduces the air density from 92.7% down to 90.5%. That is over two percent less air density from the humidity. In a bracket engine trying to select an ET within a fraction of a percent, that is cause for a win or a breakout. For an engine that is run flat out, that is cause for record performance or a burned piston.

OUTCOME: The engine is running on 2.2% less air density. That reduction affects the performance of most drag race engines. That amount of performance effect from the air reduction is somewhat complex and different for different racecars. However a good racecar setup is one in which it is at least a repeatable value. That is, for whatever air density % that results from differing combinations of pressure, temperature, and humidity, the engine performs in a predictable manner. Usually (a) more performance occurs for higher air density, and (b) lower performance occurs for lower air density. If an engine is set up with a lean fuel mixture, the opposite may be the case. When the air density drops, the mixture is no longer lean and the engine runs better. What to adjust and how much to adjust for the air density change are the skills in IHRA drag racecar tuners. Fuel system jetting, spark advance, or throttle-stop are some of the adjustments.

INSTRUMENTS: A digital Hydrometer available from several suppliers is one of the devices available to determine the water vapor pressure. Another method is the wet bulb and dry bulb method. This involves a device with thermometers (one wet and the other dry) and conversions charts.

Some of the hand-held fuel system calculators and PC software that are used by the mechanical fuel injection tuners include provisions for humidity as well as barometric pressure and temperature. Some of the suppliers are Patrick Hale (see ref.), Ralph & Spike Gorr, and Les Davenport – Acceleration Enterprise.

WATER GRAINS: This is a recent value that is circulated in conversations around many of the Pros. It is a measure of the amount of water in the air. One pound of water is 7,000 grains. At 90 deg. F and 50% relative humidity, there are approximately 107 grains of water per pound of humid air. A value of 107 grains in a pound of air is basically 107 / 7,000 grains per pound = 0.015 pounds of water in a pound of humid air.

Sparing the details, that is a little over 8 grains of water per cubic foot of air. A 400 cubic inch race engine at 100% volumetric efficiency is passing 926 cubic feet per minute of moist air at 8,000 RPM. That would then include over 7,500 grains of water per minute. That is over one pound of water per minute or over one pint per minute. The water vapor is in place of air with 23% power making oxygen for combustion. That represents the air density change of over 2% from humidity that is an influence on performance.

Grains of water are an added record to a tuners logbook. Again, (a) the fewer the grains, the less air that is displaced and the more air that remains resulting in more power. (b) The greater the grains of water, the more air that is displaced and the less air that remains resulting in less power. This field of moisture in the air is called psychrometrics. Special charts or calculators are necessary for the determination of water grains and tuning analysis.

WEATHER STATIONS FOR IHRA RACERS: Several weather station units are available for the racer. Some are lower cost and require data input from the racers instruments such as thermometer and barometer. Some require a PC. Some are turn-key. Check with the manufacturers for specific details. Also note that some pay valuable IHRA contingencies.

A. **Summit:** Weather stations by Altronics, Inc. for weather, tuning, and race tuning history (Altronics pays contingencies)

B. **Jeg’s:** Several models of weather stations are available: Speedtech, TAG Systems, Port-A-Tree, Davis instruments, Computech, & PerformAire

C. **Computech** offers a complete line of weather station units (pays contingencies)

The IHRA Junior National Events, Summit Series, and Mr. Gasket Pro-Am Tour pay contingencies for the use of Computech and Altronics, Inc. weather units.•

Reference for this article
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

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http://www.envirochex.com/Humidity.htm Air/Moisture Relationships, Envirochex, Flower Mound, TX

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http://www.4wx.com/wxcalc/vaporpressure.html 4WX Weather Calculators

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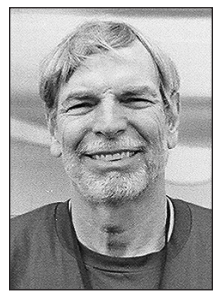

About the Author
Bob Szabo is an author, writer, and owner / driver of a blown alcohol drag racecar. The air density % presented here is a value used in his technical book: “Fuel Injection Racing Secrets.” Air density % and humidity will be covered in further detail in the author’s next book on methanol 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: pamelamarchyshyn@livenation.com or michaelperry@livenation.com