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Climbing into Thin Air

The dangers of density altitude

Photo by H Dean Chamberlain

Photo by James Williams

There is a thief among us! Without warning, it can sneak into your airplane and rob you of precious lift, thrust, and power. And, if you're not careful, it can quickly put you in a deadly spot during your next flight.

The culprit here is not something particularly obvious, nor is it something pilots who routinely fly at or near sea level are used to dealing with. But ask any high-altitude mountain flyer, and that pilot will be sure to offer firsthand accounts of the invisible danger that lurks in the long, hot days of summer—density altitude.

Consider the following report, taken from an NTSB accident narrative, which exposes the dangers of this silent, but deadly, hazard that often becomes apparent only after it's too late:

Photo by James Williams

On August 20, 2008, at 1028 MST, a Piper Cherokee *sustained substantial damage after a collision with terrain shortly after takeoff approximately one mile north of Arizona's Springerville Municipal Airport (KD68). The two occupants, a private pilot and passenger, were both killed.*

Witnesses first reported the pilot having aborted a takeoff attempt from runway 21. The pilot then taxied back to the parking area and claimed that the airplane had a flat tire(s). Inspection of the tires revealed that they were not flat, and so the pilot taxied back for takeoff, this time on runway 03. The airplane then appeared to "porpoise" during the takeoff roll and became airborne about midfield. Another witness stated that shortly after liftoff the airplane appeared to be flying "sideways" when it suddenly rolled to the right, pitched to a nose-low attitude, and impacted terrain.

NTSB's finding on the probable cause for the above accident was the pilot's failure to attain and maintain an adequate airspeed during takeoff in high density-altitude conditions, which resulted in an aerodynamic stall. Using the reported temperature (24 degrees Celsius) and altimeter setting (30.25 inches Hg), the airport at the time of the accident showed a density altitude of 9,476 feet, nearly 2,500 feet higher than field elevation. The example also shows how misleading the effects of high density altitude are, given the pilot's decision to abort the takeoff after suspecting a flat tire. The aircraft's sluggish performance was an important clue that, had it been explored more, may have saved the pilot's life.

The Lowdown on High Density Altitude

By definition, density altitude is pressure altitude corrected for nonstandard temperature. Aviation author Richard L. Collins provides an easier-to-understand definition. Collins explains density-altitude is the "only altitude understood by your airplane." What both definitions refer to requires a clear understanding of the relationship between pressure and temperature in the earth's atmosphere. When density altitude is high as a result of temperatures above standard at a given altitude, the air is less dense than normal. As a result, your aircraft will perform as if at a higher altitude with degraded climb performance and acceleration. So, instead of being a measure of height, think of density altitude more as a measure of aircraft performance.

As air becomes less dense it reduces:

- Lift (because the thin air exerts less force on the airfoils)
- Thrust (because a propeller is less efficient in thin air)
- Power (because the engine takes in less air)

As you can imagine, reducing any one of these components creates the potential for disaster, especially on a short runway with 50-foot pine trees looming at the end. Add to that equation a crosswind and a gross weight close to limits and things can quickly get interesting.

The impact of density altitude underscores the need to make it part of the preflight planning process, regardless of where you fly. Even a low-elevation airport under the right conditions can be cause for a much-longer-than-anticipated takeoff roll.

High, Hot, and Humid

Three key factors contribute to high density altitude: altitude, temperature, and humidity. The more your flight conditions lean toward the higher end of each (i.e., high, hot, and humid) the greater the performance-robbing effects you'll notice. On the flip-side, a cold dry day at a low altitude is where light planes perform best.

Keep in mind that air, as a gas, is compressed more towards the surface of the earth where it has greater density. Conversely, the farther away from the surface the less pressure is exerted, which produces air that is less dense.

When factoring temperature, a different relationship exists. Rising temperatures usually indicate a decrease in density: The warmer the air, the less dense it is. For example, an aircraft taking off at an airport at 2,000 feet above sea level on a 90-degree F day would actually "think" it is taking off at an altitude of 4,400 feet, more than twice the actual altitude.

If your flight conditions call for operations in hot and humid areas, plan for a decrease in performance.

Although it does not have as great of an impact on performance as altitude and temperature, humidity must also be considered. Moist air is less dense than dry air. High temperatures also allow air to hold more water vapor so these two factors can work together to decrease aircraft performance. For example, at 96 degrees F, the water vapor content of the air can be eight times as great as at 42 degrees F. If your flight conditions call for operations in hot and humid areas, plan for a decrease in performance. Here's a good Web site for calculating the effects of humidity on density altitude: http://wahiduddin.net/calc/density_altitude.htm.

Calculate Before You Aviate

Now that we know how damaging the effects of density altitude can be on aircraft performance, let's take a look at how to run the numbers. One formula to derive density altitude in feet is: OAT (outside air temperature) – ISA (standard air temperature) x 120 + pressure altitude in feet (determined by the altitude displayed after setting your altimeter to 29.92). Your trusty E6B can also run the calculation for you after you enter pressure altitude and OAT. Using this information in conjunction with your aircraft's pilot operating handbook (POH) performance charts will help you calculate your adjusted takeoff roll and climb rate.

The right combination of warm and humid air—even at low altitudes—can drastically impair your aircraft's performance.

Another way to calculate the effects of density altitude is with a Koch Chart (see Figure 1). Use a line to connect the airport temperature (on the left) with airport pressure altitude (on the right) assuming sea-level conditions for both. Where the line intersects the middle scale will indicate how much of a climb performance decrease to expect, as well as what percentage to add to your normal takeoff distance. Remember, this method will supply only generic information; you should reference your POH to calculate performance data specific to your aircraft.

Types of Altitude

Pilots sometimes confuse the term "density altitude" with other definitions of altitude. To review:

Indicated Altitude – Altitude shown on the altimeter using the current altimeter setting

True Altitude – Height above mean sea level (MSL)

Absolute Altitude – Height above ground level (AGL)

Pressure Altitude – Indicated altitude when an altimeter is set to 29.92 in Hg and used primarily in performance calculations and in high-altitude flight

Density Altitude – Pressure altitude corrected for non-standard temperature variations

Keep Your Cool

One of the easiest ways to avoid falling victim to density altitude is to avoid takeoffs and landings at midday, when temperatures are usually at their highest. Take advantage of cooler mornings or evenings when the effects of high density altitude are not as pronounced.

Weight is another issue that can negatively affect performance, but is something over which a pilot has more control. Keeping aircraft gross weight down can afford a pilot more flexibility when dealing with a high, hot, and humid situation. That may mean taking less fuel and cargo and/or fewer passengers.

Another item often overlooked in high density-altitude situations, especially for someone used to flying at lower elevations, is to adjust the mixture control on takeoff to maximize engine power. Consult your POH for the best mixture setting given the conditions at your airport.

Finally, as with any flight, be sure to plan for performance. Study the conditions of your flight and

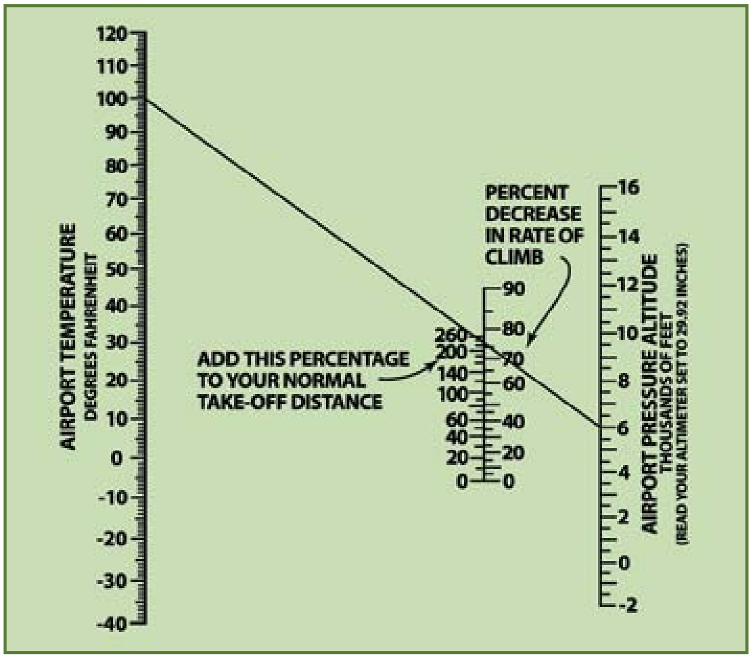

Figure 1 – Koch Chart

do the math to see how much runway you'll need for takeoff. The reduction of power and lift may require a takeoff roll longer than normal, causing some pilots to rotate too early and exacerbate an already sticky situation. Also, note how climb rates and landing distances may be affected. The NTSB accident reports include too many examples of tragedies that could have been easily avoided had pilots planned better before their flights.

"Density altitude is not just a concern for flying in the mountains," says FAASTeam National Outreach Manager Bryan Neville. "Hot temperatures can have an affect at any altitude." Neville, a former adjunct aviation professor and flight instructor with experience at both high-and low-elevation airports, suggests becoming familiar with the weight-and-balance and the performance and limitations sections of your POH or airplane flight manual.

While the effects of density altitude are more pronounced at higher elevations, the right combination of warm and humid air—even at low altitudes—can drastically impair your aircraft's performance and easily push an aircraft beyond its limits. Recognizing these limitations and keeping them a part of your preflight planning process will help keep you cool and dry, but, most importantly, safe.

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