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Dealing With Density Altitude

by Bob Carlton

Disclaimer: This article is intended to assist pilots in dealing with high elevation air show performances. It is not intended to be the final word on flying safely under high density altitude conditions. There is no substitute for you practicing your routine in your aircraft at a high elevation to determine your best procedures for safely dealing with density altitude.

What is density altitude (DA)? Density altitude is simply your actual altitude corrected for non standard temperature, pressure and humidity. Remember, the standard atmosphere is 59°F, 29.92 inches mercury and sea level. (Humidity, while a factor in performance, doesn't have near the effect of temperature and pressure.) Or in practical terms, DA is the altitude at which the aircraft "thinks" it is flying. On summer days, due to higher than standard temperatures, density altitude is almost always higher than field elevation — possibly as much as 2000'–5000' higher! For example, several of us remember the Angel Fire, NM show in July of 2004 where the DA was 13, 000' on the ground!

High DA has profound effects on engine performance, propeller performance, wing performance, true airspeed, turn radius, traverse distance along show line, pilot G tolerance, engine cooling and mixture control; all in a bad way. Let's have a look at these issues in more detail.

True Airspeed vs. Indicated Airspeed

Simply stated, the way your wing flies is a function of angle of attack (AOA for the military guys), which is related to indicated airspeed and load factor (G's). Maneuver size is a function of true airspeed.

Since high DA tends to increase true airspeed as compared to indicated airspeed, in a high DA situation, a given maneuver will be bigger for the same indicated airspeed, as opposed to the same maneuver at standard, or near standard, DA. For a given DA, airspeed can be calculated using the trusty E6B (whiz wheel). There are also a number of online true airspeed calculators and charts.

The equation for the size of any pulling (or pushing) maneuver is R = V2/F, where R is the radius of the maneuver, V is velocity (true airspeed) and F is force (G's). The controlling term in this equation is velocity. As in most speed, distance, energy equations, the effects are all related to velocity squared. This means that for a given G load, if velocity doubles, the radius quadruples! For a practical example, let's look at a simple looping maneuver under both standard, and high, DA conditions. In both cases, the indicated airspeed will be 150 knots and the pull will be 6 G's. At standard temperature and pressure (STP), the true air-speed will also be 150 knots, giving us a radius of 331 feet, or a loop diameter of 662 feet. However, if we take the same maneuver up to 5000 MSL on a 100° day, we see that the true airspeed increases to 179 knots, giving our loop a radius of 436 feet, or 872 foot diameter. This is an increase of 32%! Other performance factors, such as reduced engine and propeller performance, may increase this even more. This increase in true airspeed also translates into an increased distance traveled along the show line, which can cause errors in judging position, avoiding obstacles or "busting the box" at shows with avoid areas. The obvious situation where this can bite you is any maneuver where you are pulling hard on a down line (Reverse Cuban, Split S, Square Loop) and the unexpected increase in maneuver size leaves insufficient altitude for pullout. The less obvious place where DA can be a factor is the unexpected "unhook" at some point during the maneuver due to inadvertently increasing the AOA in a subconscious attempt to compensate for lower performance. This can happen during snaps, tumbles or even something as simple as a hard duster turn.

Planning Your High DA Routine

So with all the doom and gloom of high DA, what can we do to prepare for dealing with high DA situations? You will need to modify your routine for high DA shows. But as several of our more infamous airbosses always point out, "If you ain't done it before, don't do it here." In other words, you're going to have to practice these changes before you get to the show in High Peak, Colorado. The best situation would be to take a trip out west before the show and get some practice time. Practicing at high altitude with an imaginary hard deck will give you a feel for engine and wing performance, but not for the difference in apparent speed when close to terra firma. Also, remember to climb to the correct DA assuming a 100° day, not just to the correct

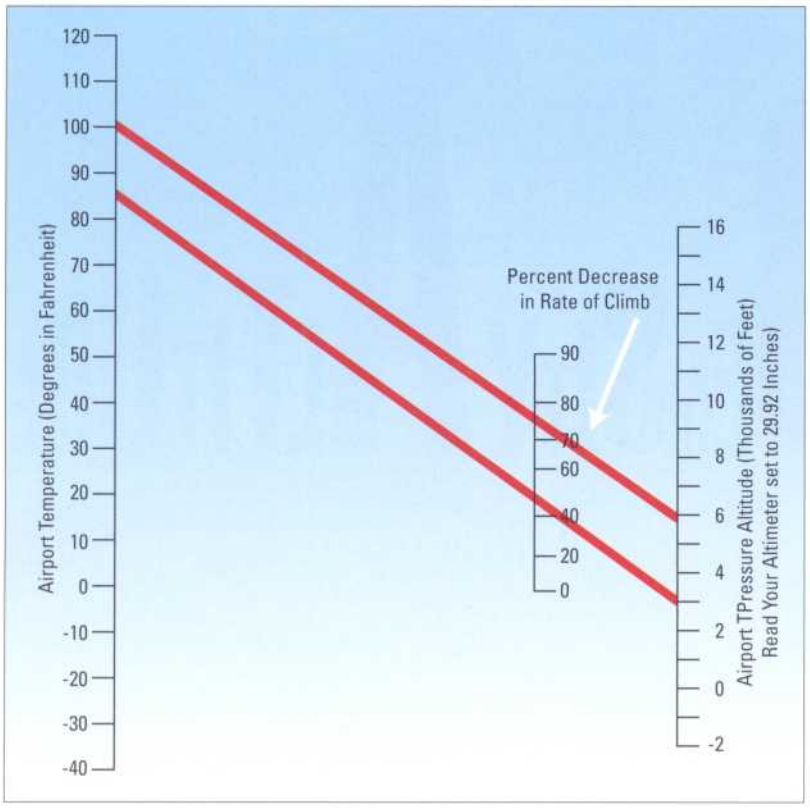

Fig. 1 Koch chart

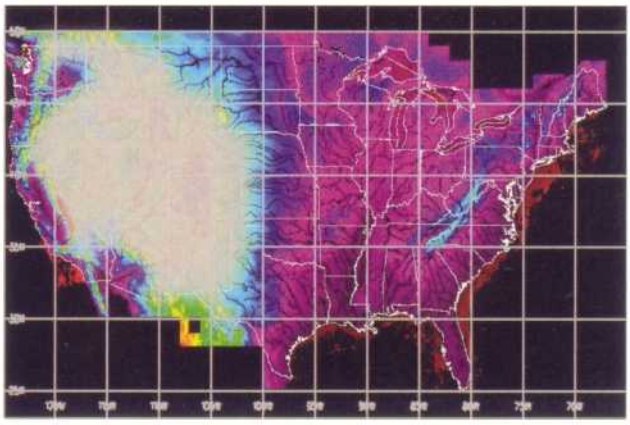

Fig. 2 US elevation map

field elevation; thus you may be climbing to 10,000' MSL to practice for a 6000' show.

So, what changes should you make to your routine for high DA shows? The most obvious change would be to add altitude to your start point. Remember, you can always bring it down if you start a bit too high. (More on this later in the article.) Chances are, no one will notice. Also, plan a break in your sequence. If you find that your energy is OK, simply make a turn and re-start the sequence.

250 feet, still inverted! Oh s**t!

Quick half roll to upright. Where am I? Midfield. Runway 300 feet to my right. Best glide speed. Gentle right turn. No spoilers. Touchdown short of the numbers. Off of runway heading. Gentle rudder turn. Tire squealing a little. Rolling straight. Whew! ... made it.

How did I get into this situation? Inverted and slow at 250' in a sailplane, when I was supposed to be at 1000'! This story took place about 10 years ago. I was flying my sailplane (unpowered) on a 250' SAC card. It was a fairly normal air show day at a show in the southwest. Field elevation was about 6000'. Nothing unusual since my home field is 6200'. My sailplane routine started normally at about 5000' AGL. I knew something wasn't right at the very beginning. The first four maneuvers should take about 1000', but this day they took more. As the routine progressed, it was obvious that I was in a big area of sink. I'd seen this before, but usually the sink subsided...not this day. As I got farther into the routine, it was obvious things weren't going well. I needed to do something, but in the stress of the moment, I couldn't for the life of me (literally) think of what to do. All I could do was fixate on my sequence card, with the mantra, "Do it the way you practiced it" running through my mind. It wasn't until I reached my 250' hard deck (inverted) that I snapped out of this trancelike state. Luckily, I had just enough altitude to slop it back to the runway.

I finally realized that I was only doing what was natural, namely reverting to my training under stress. I reworked my sequence card with several places where maneuvers could be dropped, and the sequence picked up again. I practiced each of these cuts and determined just how much altitude could be recovered. Over the years, I have had to exercise these cuts several times, just like practiced.

Be prepared to break out of your sequence at any time! While this seems obvious, our natural tendency in high stress situations is to revert to our training. We tend to fixate on doing the next maneuver. If you haven't practiced a breakaway, it is not inconceivable to fly the next maneuver right into the ground! (See sidebar.) During your off-season practice sessions, have someone on the ground call " knock it off" at unexpected points in your routine.

Change the choreography of your sequence slightly. Consider removing descending pull maneuvers, such as Reverse Cubans and Square Loops. Soften your maneuvers. Barreling your rolls slightly or pulling one less G in a loop can save lots of energy. Leave out a few snaps and tumbles. Make larger reversing turns.

Calculating Performance Loss

So how do I know how much performance I'll lose? If we break our maneuvers into two groups — powered maneuvers (loops and verticals), and gliding maneuvers (descending rolls and down lines) — we can use the Koch chart (Fig. 1) to make some ballpark calculations. The Koch Chart calculates performance loss for climb and takeoff under normal (non-aerobatic) conditions. If we make the assumption that climb performance loss equals performance loss through powered maneuvers, then we can use the chart to indicate the increase in altitude necessary for these maneuvers. Looking at the chart, we see that at 3000' MSL & 85°F, we will experience a 50% reduction in climb performance. This indicates that you should double your start altitude for powered maneuvers. At 6000' MSL & 100°F, we get a 75% reduction in climb performance, indicating the necessity to quadruple your start altitude!

For gliding maneuvers, we can use the

standard 2%/1000' air density rule. Therefore, you should add 2%/1000' to start altitude for gliding maneuvers. Using this method, we see that at 3000' & 85°F, (DA = 5500'), you should add approximately 10% to start altitude. At 6000' & 100°F, (DA = 10, 000'), add 20% to start altitude. Sounds simple, huh? Trouble is, most maneuvers are somewhere between these two definitions. So the above exercise will, at best, give you conservative numbers to start your practice. Remember, there is no substitute for you practicing your routine in your aircraft at a high elevation!

Other Factors

Other factors to consider at high DA shows are reduced pilot G tolerance, which can substantially reduce your ability to cope with unexpected situations. Poor engine cooling in the thin air may require a reduction of power or a break to allow temperatures to return to normal. Hilly terrain in the air show box (invariably with an antenna tower on top) can be a subtle killer. Inconsistent or high horizon can cause you to misinterpret your attitude, and rotor downwash downwind of ridges can cause turbulent, descending air. All of these situations are common in the mountain west.

Still More Factors

Most aircraft altimeters can't be set to 0 above 3000'. So, on top of everything else, you're now required to do mental calculations to keep track of absolute altitude! The trick I use is simply setting to the nearest even thousand (2000, 4000, 6000), and marking absolute altitude with dry erase marker on the face of the altimeter. Setting to the nearest even allows me to fly the routine as even-odd altitude. Since most of us rarely go above 2000' AGL, this even-odd approach requires only that I recognize the ground as the next even number any time I' m below 2000' AGL.

Proposed Altitude Restriction

Due to the high number of recent accidents attributed to high DA, the ACE Committee is considering a new SAC card restriction for high elevation shows. While this is far from finished, the restriction may look something like this:

"Anyone with a surface level card who has not flown at least 5 performances at a minimum of 3 venues above an elevation of 3000' MSL, will have a 250' restriction placed on their card for shows above 3000' elevation."

The idea behind this new rule is to provide an artificial hard deck "wake up call." If you find yourself below the 250' limit, knock it off!

The areas of the country affected by this proposed rule are shown in figure 2. Basically, it includes all (or most) of Colorado, New Mexico, Utah and Wyoming, and parts of Arizona (not Phoenix), California (not the coastal areas), Washington (not the coastal areas), Idaho, Montana, Nevada and Oregon. These areas represent only a small fraction of the country's air shows.

I consider myself fortunate to have learned to fly in the mountain west. The great weather, awesome scenery and fantastic soaring conditions are some of the best in the world. My practice box is at 7000' MSL, and often has a DA of over 10,000'. My first taste of DA was an incredible in-crease in performance at my first shows in the mid-west. I didn't know what to do with all that extra power. Unfortunately, most of our large population centers, and therefore most of our pilots, are at consider-ably lower elevations. High DA should command respect from all of us. Fly safe.