Federal Aviation Administration

Density Altitude

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Note: This document was adapted from the original Pamphlet P-8740-2 on density altitude.

Introduction

Although density altitude is not a common subject for "hangar flying" discussions, pilots need to understand this topic. Density altitude has a significant (and inescapable) influence on aircraft and engine performance, so every pilot needs to thoroughly understand its effects. Hot, high, and humid weather conditions can cause a routine takeoff or landing to become an accident in less time than it takes to tell about it.

Density Altitude Defined

Types of Altitude

Pilots sometimes confuse the term "density altitude" with other definitions of altitude. To review, here are some types of altitude:

- **Indicated Altitude** is the altitude shown on the altimeter.
- **True Altitude** is height above mean sea level (MSL).
- **Absolute Altitude** is height above ground level (AGL).
- **Pressure Altitude** is the indicated altitude when an altimeter is set to 29.92 in Hg (1013 hPa in other parts of the world). It is primarily used in aircraft performance calculations and in high-altitude flight.
- **Density Altitude** is formally defined as "pressure altitude corrected for nonstandard temperature variations."

Why Does Density Altitude Matter?

High Density Altitude = Decreased Performance

The formal definition of density altitude is certainly correct, but the important thing to understand is that density altitude is an indicator of aircraft performance. The term comes from the fact that the density of the air decreases with altitude. A "high" density altitude means that air density is reduced, which has an adverse impact on aircraft performance. The published performance criteria in the Pilot's Operating Handbook (POH) are generally based on standard atmospheric conditions at sea level (that is, 59 ^{o}F or 15 ^{o}C. and 29.92 inches of mercury). Your aircraft will not perform according to "book numbers" unless the conditions are the same as those used to develop the published performance criteria. For example, if an airport whose elevation is 500 MSL has a reported density altitude of 5,000 feet, aircraft operating to and from that airport will perform as if the airport elevation were 5,000 feet.

High, Hot, and Humid

High density altitude corresponds to reduced air density and thus to reduced aircraft performance. There are three important factors that contribute to high density altitude:

1. **Altitude.** The higher the altitude, the less dense the air. At airports in higher elevations, such as those in the western United States, high temperatures sometimes have such an effect on density altitude that safe operations are impossible. In such conditions, operations between midmorning and midafternoon can become extremely hazardous. Even at lower elevations, aircraft performance can become marginal and it may be necessary to reduce aircraft gross weight for safe operations.

2. **Temperature.** The warmer the air, the less dense it is. When the temperature rises above the standard temperature for a particular place, the density of the air in that location is reduced, and the density altitude increases. Therefore, it is advisable, when performance is in question, to schedule operations during the cool hours of the day (early morning or late afternoon) when forecast temperatures are not expected to rise above normal. Early morning and late evening are sometimes better for both departure and arrival.
3. **Humidity.** Humidity is not generally considered a major factor in density altitude computations because the effect of humidity is related to engine power rather than aerodynamic efficiency. At high ambient temperatures, the atmosphere can retain a high water vapor content. For example, at 96 °F, the water vapor content of the air can be eight (8) times as great as it is at 42 °F. High density altitude and high humidity do not always go hand in hand. If high humidity does exist, however, it is wise to add 10 percent to your computed takeoff distance and anticipate a reduced climb rate.

Check the Charts Carefully

Whether due to high altitude, high temperature, or both, reduced air density (reported in terms of density altitude) adversely affects aerodynamic performance and decreases the engine's horsepower output. Takeoff distance, power available (in normally aspirated engines), and climb rate are all adversely affected. Landing distance is affected as well; although the indicated airspeed (IAS) remains the same, the true airspeed (TAS) increases. From the pilot's point of view, therefore, an increase in density altitude results in the following:

- Increased takeoff distance.
- Reduced rate of climb.
- Increased TAS (but same IAS) on approach and landing.
- Increased landing roll distance.

Because high density altitude has particular implications for takeoff/climb performance and landing distance, pilots must be sure to determine the reported density altitude and check the appropriate aircraft performance charts carefully during preflight preparation. A pilot's first reference for aircraft performance information should be the operational data section of the aircraft owner's manual or the Pilot's Operating Handbook developed by the aircraft manufacturer. In the example given in the previous text, the pilot may be operating from an airport at 500 MSL, but he or she must calculate performance as if the airport were located at 5,000 feet. A pilot who is complacent or careless in using the charts may find that density altitude effects create an unexpected—and unwelcome—element of suspense during takeoff and climb or during landing.

If the airplane flight manual (AFM)/POH is not available, use the Koch Chart to calculate the approximate temperature and altitude adjustments for aircraft takeoff distance and rate of climb.

At power settings of less than 75 percent, or at density altitude above 5,000 feet, it is also essential to lean normally aspirated engines for maximum power on takeoff (unless the aircraft is equipped with an automatic altitude mixture control). Otherwise, the excessively rich mixture is another detriment to overall performance. *Note: Turbocharged engines need not be leaned for takeoff in high density altitude conditions because they are capable of producing manifold pressure equal to or higher than sea level pressure.*

Density Altitude Charts

Density Altitude Rule-of-Thumb Chart

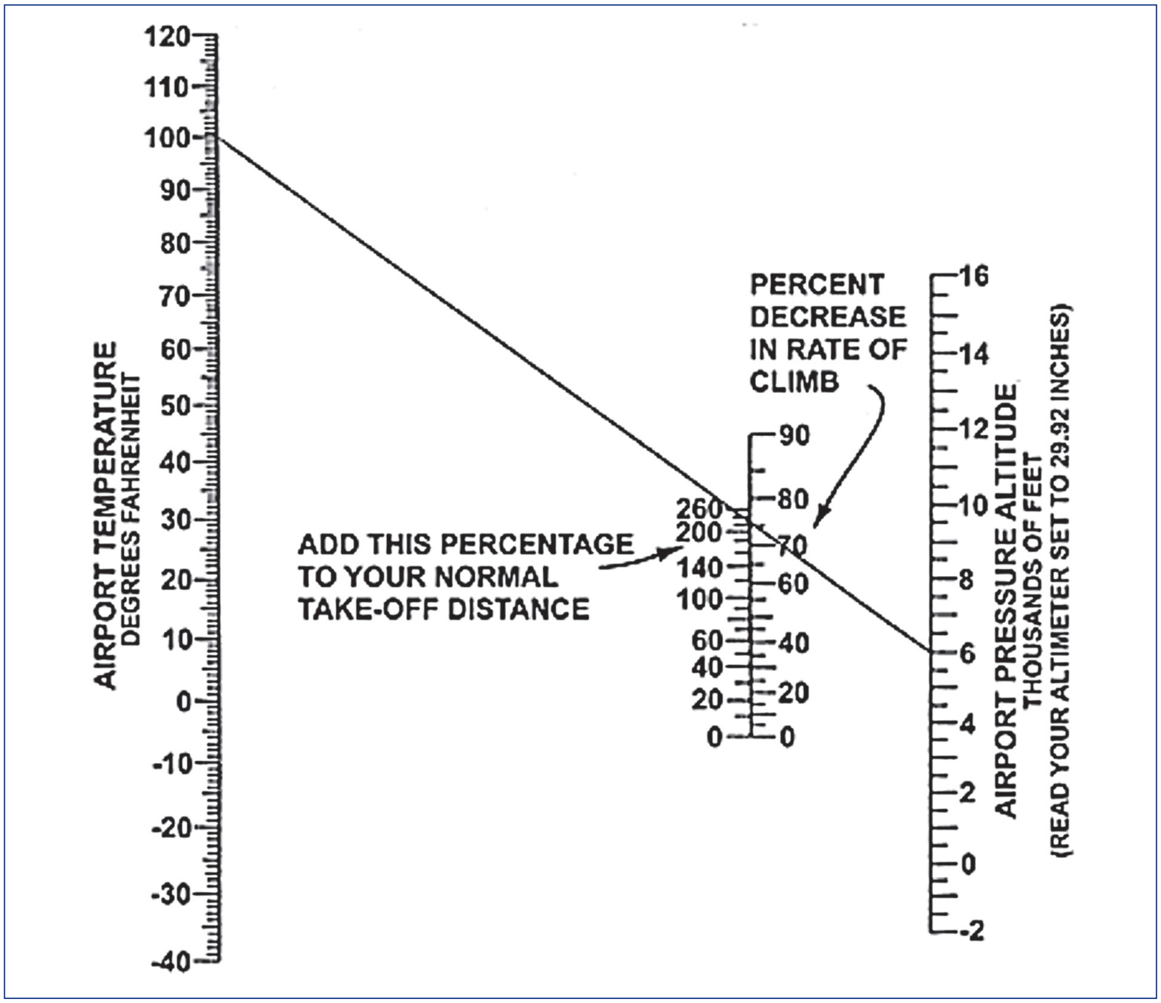
The chart below illustrates an example of temperature effects on density altitude.

Density Altitude Rule-of-Thumb Chart

STD TEMP	ELEV/TEMP	80 °F	90 °F	100 °F	110 °F	120 °F	130 °F
59 °F	Sea level	1,200	1,900	2,500	3,200	3,800	4,400
52 °F	2,000	3,800	4,400	5,000	5,600	6,200	6,800
45 °F	4,000	6,300	6,900	7,500	8,100	8,700	9,400
38 °F	6,000	8,600	9,200	9,800	10,400	11,000	11,600
31 °F	8,000	11,100	11,700	12,300	12,800	13,300	13,800

Koch Chart

To find the effect of altitude and temperature, **connect** the temperature and airport altitude by a straight line. **Read** the increase in takeoff distance and the decrease in rate of climb from standard sea level values.



For example, the diagonal line shows that 230 percent must be added for a temperature of 100 °F and a pressure altitude of 6,000 feet. Therefore, if your standard temperature sea level takeoff distance normally requires 1,000 feet of runway to climb to 50 feet, it would become 3,300 feet under the conditions shown in the chart. In addition, the rate of climb would be decreased by 76 percent. Also, if your normal sea level rate of climb is 500 feet per minute, it would become 120 feet per minute.

This chart indicates typical representative values for "personal" airplanes. For exact values, consult your AFM/POH. The chart may be conservative for airplanes with supercharged engines. Also, remember that long grass, sand, mud, or deep snow can easily double your takeoff distance.

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