Accident Prevention Program

DENSITY ALTITUDE

When it comes to good old-fashioned hangar flying sessions, one subject that almost never seems to be discussed is density altitude. The reason being, too many pilots do not know enough about the subject. Yet, because of the unescapable influence density altitude has on aircraft and engine performance, it is important for every pilot to understand its effects. Hot, high, and humid weather conditions can change a routine takeoff or landing into an accident in less time than it takes to tell about it. There are three important factors that affect air density.

1. **Altitude**. The higher the altitude, the less dense the air.
2. **Temperature**. The warmer the air, the less dense it is.
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 degrees F, the water vapor content of the air can be eight (8) times as great as at 42 degrees F. High density altitude and high humidity do not often go hand-in-hand. However, if high humidity does exist, it would be wise to add 10% to your computed takeoff distance and anticipate a reduced climb rate.

The Pilot's Operating Handbooks prepared by the Airframe Manufacturers provide good information regarding the aircraft performance under standard conditions (sea level at 59 degrees F). However, if a pilot becomes complacent regarding aircraft performance or is careless in using the charts, density altitude effects may provide an unexpected element of suspense during takeoff and climb.

Density altitude effects are not confined to mountain areas. They also apply at elevations near sea level when temperatures go above standard 59 degrees F or 15 degrees C). It's just that the effects are increasingly dramatic at the higher elevations. Takeoff distance, power available (in normally aspirated engines), and climb rate are all adversely affected, and while the indicated airspeed remains the same, the true airspeed increases. Too often, a pilot who is flying in high density altitude conditions for the first time in an aircraft with a normally aspirated engine becomes painfully aware of the retarded effect on the aircraft performance capabilities.

Additionally, at power settings of less than 75%, or at density altitudes above 5,000 feet, it is essential that normally aspirated engines be leaned for maximum power on takeoff unless equipped with an automatic altitude mixture control. Otherwise, the excessively rich mixture adds another detriment to overall performance. Turbocharged engines, on the other hand, 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 is not to be confused with pressure altitude, indicated altitude, true altitude or absolute altitude, and is not to be used as a height reference, but will be used as determining criteria for the performance capabilities of the aircraft. The published performance criteria in the Pilot's Operating Handbook is generally based on standard atmospheric conditions at sea level (59 degrees F to 15 degrees C and 29.92 inches of mercury).

When the temperature rises above the standard temperature for the locality, the density of the air in that locality is reduced and the density altitude increases. This affects the aircraft aerodynamic performance, and decreases the horsepower Output of the engine. Pilots should; make a practice of checking their aircraft performance charts during preflight preparation. This is important when temperatures are above normal regardless of airport elevation.

This chart gives a rule of thumb example of temperature affects on density altitude.

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

From the pilot's point of view, an increase in density altitude results in:

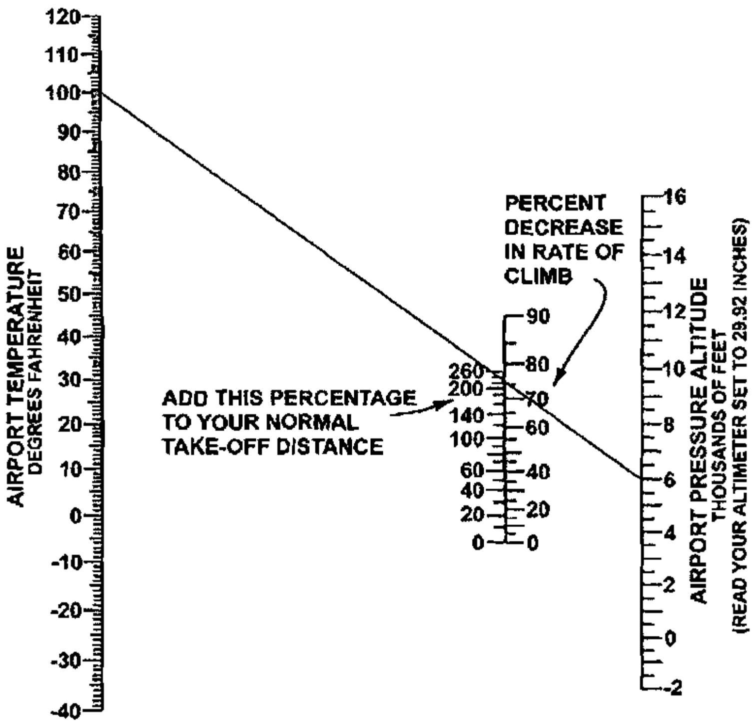
1. Increased takeoff distance.
2. Reduced rate of climb.
3. Increased true airspeed on approach and landing (same IAS).
4. Increased landing roll distance.

At airports of 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. 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 expected to rise above normal. Early morning and late evening are sometimes more ideal for both departure and arrival.

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. When these references are not available, the Koch Chart may be used to figure the approximate temperature and altitude adjustments for aircraft takeoff distance and rate of climb.

The Koch Chart for Altitude and Temperature Effects

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



Example: The diagonal line shows that 230% must be added for a temperature of 100 degrees and a pressure altitude of 6,000 feet. Therefore, if your standard temperature sea level take-off distance, in order to climb to 50 feet, normally requires 1,000 feet of runway, it would become 3,300 feet under the conditions shown. In addition, the rate of climb would be decreased 76%. 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 airplane flight manual. The chart may be conservative for airplanes with supercharged engines. Also remember that long grass, sand, mud or deep snow can easily double your take-off distance.

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Chapter 10

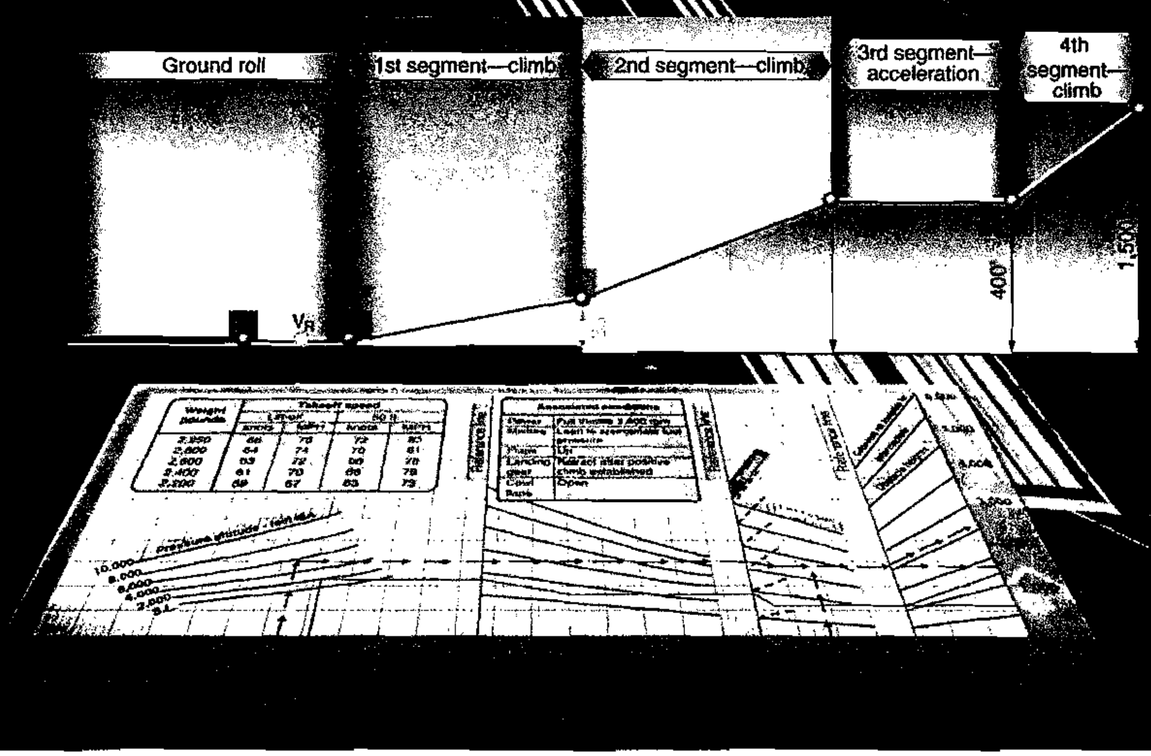
Aircraft Performance

Introduction

This chapter discusses the factors that affect [illegible] performance, which include the aircraft weight, [illegible] conditions, runway environment, and the fundamental physical laws governing the forces acting on aircraft.

Importance of Performance Data

The performance or operational information section of the Aircraft Flight Manual/Pilot's Operating Handbook (AFM/POH) contains the operating data for the aircraft; that is, the data pertaining to takeoff, climb, range, endurance, descent, and landing. The use of this data in flying operations is mandatory for safe and efficient operation. Considerable knowledge and familiarity of the aircraft can be gained through study of this material.



Altitude (ft)	Pressure ("Hg)	Temperature (°C)	(°F)
0	29.92	15.0	59.0
1,000	28.86	13.0	55.4
2,000	27.82	11.0	51.9
3,000	26.82	9.1	48.3
4,000	25.84	7.1	44.7
5,000	24.89	5.1	41.2
6,000	23.98	3.1	37.6
7,000	23.09	1.1	34.0
8,000	22.22	–0.9	30.5
9,000	21.38	–2.8	26.9
10,000	20.57	–4.8	23.3
11,000	19.79	–6.8	19.8
12,000	19.02	–8.8	16.2
13,000	18.29	–10.8	12.6
14,000	17.57	–12.7	9.1
15,000	16.88	–14.7	5.5
16,000	16.21	–16.7	1.9
17,000	15.56	–18.7	–1.6
18,000	14.94	–20.7	–5.2
19,000	14.33	–22.6	–8.8
20,000	13.74	–24.6	–12.3

Figure 10-2. *Properties of standard atmosphere.*

Since all aircraft performance is compared and evaluated with respect to the standard atmosphere, all aircraft instruments are calibrated for the standard atmosphere. Thus, certain corrections must apply to the instrumentation, as well as the aircraft performance, if the actual operating conditions do not fit the standard atmosphere. In order to account properly for the nonstandard atmosphere, certain related terms must be defined.

Pressure Altitude

Pressure altitude is the height above the standard datum plane (SDP). The aircraft altimeter is essentially a sensitive barometer calibrated to indicate altitude in the standard atmosphere. If the altimeter is set for 29.92 "Hg SDP, the altitude indicated is the pressure altitude—the altitude in the standard atmosphere corresponding to the sensed pressure.

The SDP is a theoretical level where the pressure of the atmosphere is 29.92 "Hg and the weight of air is 14.7 psi. As atmospheric pressure changes, the SDP may be below, at, or above sea level. Pressure altitude is important as a basis for determining aircraft performance, as well as for assigning flight levels to aircraft operating at above 18,000 feet.

The pressure altitude can be determined by either of two methods:

1. By setting the barometric scale of the altimeter to 29.92 "Hg and reading the indicated altitude, or
2. By applying a correction factor to the indicated altitude according to the reported "altimeter setting."

Density Altitude

The more appropriate term for correlating aerodynamic performance in the nonstandard atmosphere is density altitude—the altitude in the standard atmosphere corresponding to a particular value of air density.

Density altitude is pressure altitude corrected for nonstandard temperature. As the density of the air increases (lower density altitude), aircraft performance increases. Conversely, as air density decreases (higher density altitude), aircraft performance decreases. A decrease in air density means a high density altitude; an increase in air density means a lower density altitude. Density altitude is used in calculating aircraft performance. Under standard atmospheric condition, air at each level in the atmosphere has a specific density; under standard conditions, pressure altitude and density altitude identify the same level. Density altitude, then, is the vertical distance above sea level in the standard atmosphere at which a given density is to be found.

The computation of density altitude must involve consideration of pressure (pressure altitude) and temperature. Since aircraft performance data at any level is based upon air density under standard day conditions, such performance data apply to air density levels that may not be identical to altimeter indications. Under conditions higher or lower than standard, these levels cannot be determined directly from the altimeter.

Density altitude is determined by first finding pressure altitude, and then correcting this altitude for nonstandard temperature variations. Since density varies directly with pressure, and inversely with temperature, a given pressure altitude may exist for a wide range of temperature by allowing the density to vary. However, a known density occurs for any one temperature and pressure altitude. The density of the air, of course, has a pronounced effect on aircraft and engine performance. Regardless of the actual altitude at which the aircraft is operating, it will perform as though it were operating at an altitude equal to the existing density altitude.

For example, when set at 29.92 "Hg, the altimeter may indicate a pressure altitude of 5,000 feet. According to the AFM/POH, the ground run on takeoff may require a distance of 790 feet under standard temperature conditions.

However, if the temperature is 20 °C above standard, the expansion of air raises the density level. Using temperature correction data from tables or graphs, or by deriving the

Library Contents

Density Altitude - P-8740-2
Author: Federal Aviation Administration *Date: Unknown*

Introduction

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

Density altitude is not a common subject for "hangar flying" discussions, but pilots do need to understand this topic. Density altitude has a significant (and inescapable) influence on aircraft and engine performence, so every pilot needs to thoroughly understand its effects. Hot, high, and humid weather conditions can change e routine takeoff or landing into 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:

- **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 en 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 es " pressure altitude corrected for non-standard temperature variations."

Why does Density Altitude Matter?

High Density Alitude = 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 meens that air density is reduced, which has an adverse impact on aircraft performance. The published performance criteria in the Pilot's Operating Handbook is generally based on standard atmospheric conditions at sea level (i.e., 59 degrees F. to 15 degrees 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. If, for example, an airport whose elevation is 500 MSL has e reported density altitude of 5,000 feet, aircraft operating to and from that airport will perform as if the airport elevation was 5,000.

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:

- **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 midmoming and midaftemoon 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 operetions.
- **Temperature.** The warmer the air, the less dense it is. When the temperature rises above the standard temperatura for a perticular placo, 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 operetions during the cool hours of the day, early moming or late aftemoon, when forecast temperatures are expected to rise above normal. Early moming and late evening are sometimes better for both departure and arrival.
- **Humidity.** Humidity is not generally considered a major factor in density altitude computations, because the effect of humidity is related to engine power rether than aerodynamic efficiency. At high ambient temperatures, the atmosphere cen retain a high water vapor content. For example, at 96 degrees F, tha water vapor content of the air can be eight (8) times as great as et 42 degrees F. High density altitude and high humidity do not always go hand-in-hand. However, if high humidity does exist, 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 horsepower output of the engine. Takeoff distance, power available (in normally aspirated engines), and climb rate are all adversely affected. Landing distance is affected as wall: while the indicated airspeed remains the same, the true airspeed incraases. From the pilot's point of view, therefore, an increase in density altitude results in:

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

Beceuse high density altitude has perticular implications for takeoff/climb performance end 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 Opereting Handbook developed by the aircraft manufacturer. In the example given above, the pilot mey 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 AFM/POH is not available, use the Koch Chart (*see next chapter*) 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 et density altitudes 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, as 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 a "rule of thumb" example of temperature effects on density altitude.

Density Altitude "Rule of Thumb" Chart

STD TEMP	ELEV/TEMP	80 deg F	90 deg F	100 deg F	110 deg F	120 deg F	130 deg F
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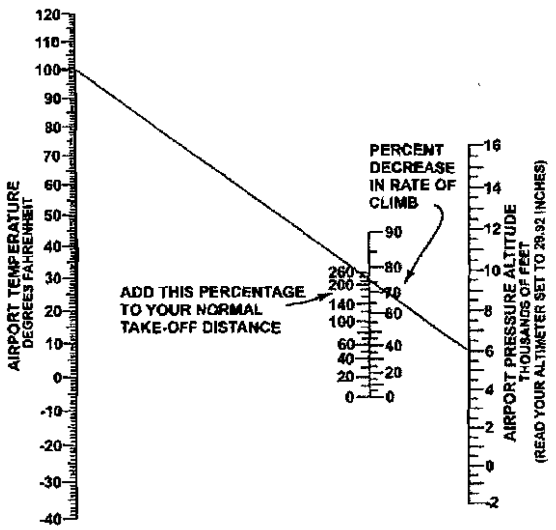
45 deg F	4,000	6,300	6,900	7,500	8,100	8,700	9,400
38 deg F	6,000	8,600	9,200	9,800	10,400	11,000	11,600
31 deg F	8,000	11,100	11,700	12,300	12,800	13,300	13,800

Koch Chart

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



Example: The diagonal line shows that 230 percent must be added for a temperature of 100 degrees and a pressure altitude of 6,000 feet. Therefore, if your standard temperature sea level take-off distance, in order to climb to 50 feet, normally requires 1,000 feet of runway, it would become 3,300 feet under the conditions shown. In addition, the rate of climb would be decreased 76 percent. Also, if your normal sea level rate of climb is 500 feet per minute, it would become 120 feet per minute.

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About This Series

The purpose of this series of Federal Aviation Administration (FAA) Aviation Safety Program publications is to provide the aviation community with safety information that is informative, handy, and easy to review. Meny of the publications in this series summarize material published in various FAA advisory circulars, handbooks, other publications, and various audiovisual products developed by the FAA and used in its Aviation Safety Program.

Some of the ideas an materials in this series were developed by the aviation industry. The FAA acknowledges the support of the avielion industry and its various trade and membership groups in the production of this series.

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