Altimeters & Altitudes – Part 1

According to the **FAA Pilots Handbook of Aeronautical Knowledge** altitudes come in several flavors.

True altitude
Absolute altitude
Indicated Altitude
Calibrated altitude
Pressure altitude
Density altitude

Three of them are actual distances above something. Two of them are basically the same, and one is for reference only. (Do you know which they are?)

<u>True altitude</u> is how high you are above the "average level of the sea", Mean Sea Level (MSL).

<u>Absolute altitude</u> is how high you are above the ground.

<u>Indicated altitude</u> is whatever the hands of your altimeter is currently showing. If the altimeter is set to the most current altimeter setting under most conditions the Indicated Altitude will be fairly close to your elevation above sea level MSL.

<u>Calibrated altitude</u> is indicated altitude corrected for instrument error.

<u>Pressure altitude</u> is how high we are above the place in the atmosphere where the atmospheric pressure is 29.92 inches of mercury. ("Hg). Pressure altitude is used for several things associated with flying.

<u>Density altitude</u> is the altitude the airplane "feels" like it's at when it comes to performance. It's mostly used for "go, no-go" takeoff decisions at high altitude airports when the atmospheric pressure and temperature are "non-standard". Density Altitude has an effect on the performance of the engine and the airplane.

We'll meet all of these altitudes later and learn more about what they mean and how to use them. But first, before we get into the nitty-gritty, let's do a quick review from the "Altimeter – How it works" section.

<u>Atmospheric Pressure</u>

The weight of the air particles above the measuring device. For our purpose barometric pressure is measured by mercury or aneroid barometers and reported in inches of mercury ("Hg). The altimeter has an aneroid barometer sealed inside the altimeter case.

International Standard Atmosphere (ISA)

"At sea level the atmospheric pressure is 29.92 "Hg, the temperature is 15 degrees centigrade and for each 1,000 feet of elevation change the pressure changes one (1) "Hg and the temperature changes 2 degrees centigrade". The change in pressure and temperature are called the "standard lapse rates".

"Standard" pressure and temperature decrease going up in elevation, and increase coming down by the amount of the standard lapse rates. Note: That defines the behavior of ISA STANDARD pressure and temperature. Actual pressure/temperature does whatever they want to. This will turn out to be very important.

Indicated Altitude

Some of this is sort of a repeat from the "How an Altimeter works" section, but worth repeating….

Indicated Altitude is whatever the hands are currently showing on the face of the altimeter. This is VERY important to remember, only under certain conditions is the Indicated Altitude actually your feet above sea level (MSL).

For practicable purposes however, if you have the Kollsman window set to the current altimeter setting issued from the closest reporting station, then the Indicated Altitude is a pretty good ***indication*** of your height above the average level of the sea (MSL). However, as we've learned, altimeters are only completely correct when setting on the ground at the station reporting the altimeter setting, or in the rare case when flying in "standard" atmospheric conditions.

Let's take a specific case. We're setting on the ramp at Alliance airport ready to go on a trip to Colorado. We get the current altimeter setting, put it in the Kollsman window and the hands say 723 feet Indicated Altitude, the field elevation at Alliance, so far so good. At this moment the Indicated Altitude is also our actual height above sea level (MSL). We decide to fly at 5,000 feet to Amarillo where we'll stop for gas. We takeoff, point the nose toward Amarillo, climb to 5,000 feet and level off.

After a while we notice we've inched up to 5,200 Indicated Altitude so we drop the nose and descend back to 5,000. These little variations in altitude continue to happen so we mess with the trim a bit. When we get near Wichita Falls the voice on the radio gives us an updated altimeter setting, we put it in the Kollsman window and notice the altimeter now says 4,500 Indicated Altitude, just a minute ago it said 5,000 feet. What's going on we ask?

Here's what's going on. When we were setting on the ramp back at Alliance the aneroid wafers in the altimeter had been busy expanding and contracting in relationship to the actual atmospheric pressure that was passing over the airport that day. When we set the Kollsman window to the current altimeter setting it made the hands say field elevation, but doing so had NO effect on the aneroid wafers, they were busy doing their own thing.

All was well so we took off and climbed to an Indicated Altitude of 5,000 feet. As we were climbing the pressure was dropping, the wafers were expanding causing the hands to show an increase in altitude. At some point the wafers had expanded to the point where the hands said 5,000 feet Indicated Altitude so we leveled off.

But, as we moseyed our way along flying straight and level the actual atmospheric pressure was changing and in this example the pressure was decreasing, which caused the wafers to expand a little making the hands show an increase in altitude when none had actually happened. That's when we noticed we had "climbed" to 5,200 and we dropped the nose a bit to get back to 5,000. In reality we weren't flying at 5,000 feet at all, we were "following" the 5,000 foot pressure level and it was moving down as we made our way toward Amarillo.

When we got to Wichita Falls and set the Kollsman window with the updated altimeter setting it moved the hands on the dial and we learned we were NOT at 5,000 feet, we were actually closer to 4,500 feet. The 5,000 foot pressure level had descended 500 feet, but we didn't know it because we still had the original altimeter setting from takeoff at Alliance.

The original altimeter setting at Alliance was just a "known starting point" for measuring altitude and was only really accurate while setting on the ground at Alliance. Also, remember the altimeter was designed so that for a 1 "Hg change in pressure, the wafers would expand/contract a specific amount, and that amount would cause the hands to move 1,000 feet. But the fact is the 1 "Hg change in pressure can happen in any amount of actual distance, but the hands will still show a 1,000 foot change in altitude, even if it's wrong!

What made the 5,000 foot pressure level descend?

Here's what. Mother Nature sent an air mass along your path of flight, which had an atmospheric pressure of whatever she wanted, she put the 5,000 foot pressure level where she wanted, and she didn't have to ask anybody's permission. Additionally, she hasn't read the International Standard Atmosphere (ISA) document and she's not going to. Another "got-ya" is when air temperature gets colder the pressure levels also descend.

Well, with this kind of attitude from Mother Nature and knowing that the altimeter man designed the altimeter to only work correctly in ISA standard conditions it seems to me there may be an opportunity for confusion.

Does all this really matter?

No, not too much, as long as we clearly understand what we're dealing with and everybody's altimeter is set to the current altimeter setting and the error caused by non-standard pressure and temperature is not toooo great and, & and …….., oh well, you get the picture.

The saving fact is everybody's altimeter is affected in the same way by non-standard atmospheric conditions, so whatever the variances are it effects everyone equally and so it doesn't really matter if everybody's off a little, so long as it's just a little and it's the same amount for everyone. (More on non-standard temperature later)

All the aircraft in the air around you have the same information and their altimeters work the same as yours, so separation requirements are still met. Also, when you come in to land the closer you get to the ground (where the current altimeter setting was calculated), the more accurate the altimeter becomes. What matters the most is that you, and everyone else, keeps the altimeter set to the most current altimeter setting available. The Pilots Handbook of Aeronautical Knowledge says to keep the altimeter set to the current setting from a station within 100 NM.

The biggest concern is if you have to fly long distances without getting an updated altimeter setting where there are tall obstacles (such as mountains) and there is a significant drop in either pressure, or temperature, then “look out below”. If you’re about halfway between reporting stations pick the one in front of you.

Indicated Altitude is where we fly. With a properly set altimeter Indicated Altitude is used to fly instrument approaches, traffic patterns, altitudes assigned by ATC, etc. For flight operations below 18,000 feet MSL the altimeter should be set to the current altimeter setting. 18,000 feet MSL and above the Kollsman window is set to 29.92, the Indicated Altitude is then the current Pressure Altitude and altitudes are referred to as “Flight Levels”.

Some additional bits of wisdom

According to the FAA if you’ve adjusted the Kollsman window to the current altimeter setting and you’re setting on the ground the Indicated Altitude should read field evaluation, +/- 75 feet, if it doesn’t – somethings not right and you should take your altimeter to the doctor. While on the ground with the current altimeter setting in the Kollsman window the Indicated Altitude is also the True Altitude, the actual feet above mean sea level. (More on True Altitude in Part 2).

If you’re on the ground at a field that does not have altimeter reporting capabilities, set the altimeter to field elevation. The Indicated Altitude reading in the Kollsman window will be real close to the current altimeter setting and you’ll be fine until you can get an updated setting.

Your altimeter knows how to measure the weight of the column of air above it. But, the altimeter is inside the airplane which might be shielding the altimeter from “feeling” this weight. Not to worry, your airplane has a “static air vent” somewhere on the outside of the plane. The altimeter is connected to the static air vent, which lets the altimeter “feel” the outside pressure. The preflight checklist says to make sure the static air vent is open and not blocked, without the static air vent the altimeter doesn’t have a clue.

Altimeters are mechanical instruments which may have slight mechanical errors. When the altimeter has been calibrated (adjusted) to compensate for these errors the Indicated Altitude shown is technically called the *Calibrated Altitude*.

Pressure Altitude

Pressure Altitude is how high you are above a layer of atmosphere where the pressure is 29.92 “Hg. This “reference plane” is not always at the same place, it varies up/down depending on current atmospheric conditions. If the atmospheric pressure where you are is 28.92 “Hg then in accordance with the ISA standard lapse rate for pressure, your Pressure Altitude is 1,000 feet above the 29.92 “Hg reference plane. Pressure Altitude is used in calculations for True Air Speed, True Altitude and Density Altitude. It’s also where we fly at altitudes 18,000 feet MSL and above.

Aircraft takeoff, landing and climb performance data is shown assuming the airplane is at gross weight, at sea level on an ISA standard day, standard days almost never exist. Aircraft performance is affected by atmospheric pressure, so it’s important to know how to interpret performance data for your plane and this starts with knowing the Pressure Altitude. Atmospheric pressure varies a lot, it’s not a fixed number.

There are three ways to determine Pressure Altitude. From a chart, by setting the Kollsman window to 29.92, or by a math formula.

The formula might be the most accurate, setting the altimeter to 29.92 and reading the Indicated Altitude is the easiest, the chart method is used on the FAA private pilot written test.

If you're in the air, simply set the Kollsman window to 29.92 and read the Indicated Altitude as Pressure Altitude. If you're on the ground you can use the formula, or chart methods. (You could also get in the plane and use the altimeter method).

The "on the ground" formula is:
PA = (29.92 – current altimeter setting) X 1,000 + field elevation

Here's an example:
Current altimeter setting is 29.87 "Hg
Field elevation is 723 feet MSL

Using the formula
PA = [(29.92 – 29.87) x 1,000] + 723
PA = (.05 X 1,000) + 723
PA = 50 + 723
PA = 773 feet (PA is MORE than field elevation)

Another example with altimeter setting of 30.00
PA = [(29.92 – 30.00) X 1,000] + 723
PA = (-.08 X 1,000) + 723
PA = -80 + 723
PA = 643 feet (PA is LESS than field elevation)

Using Pressure Altitude to calculate Density Altitude and True Altitude is explained in the next section.