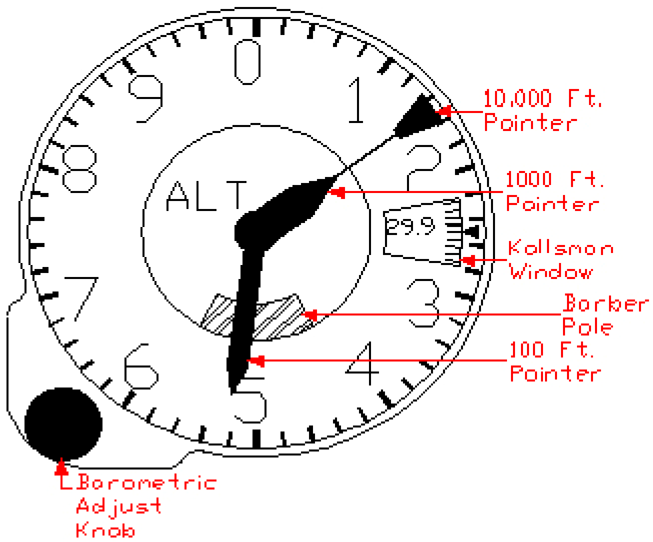
INTRODUCTION

A pressure altimeter tells the pilot the altitude of the aircraft above a level. It provides an indication of altitude by measuring the atmospheric pressure. An altimeter works like an aneroid barometer.

As the aircraft climb away from the surface of the earth, the air pressure falls. This is due to the height of the column of air above it decreasing, and therefore lowering the weight and pressure exerted by that column. If the air pressure at sea level and the rate at which pressure falls with height are known, it is then possible to determine the altitude from the pressure of any point above sea level. (Kermode, 2006)

Figure 1: The Sensitive Altimeter (tghaviation.com)



THE ATMOSPHERE

International Standard Atmosphere

As real atmospheric conditions are never constant, a standard against which the actual atmospheric properties at any time or place and aircraft/engine performance can be compared is required. For this reason, the ISA is adopted. It is a hypothetical model that provides an approximation to the conditions that may be expected. It provides precise definitions of values for lapse rate, height of the tropopause and sea level temperature, density and pressure. Air is assumed to be a perfect gas, without any dust, moisture, water vapour and at rest with respect to earth. (Mustafa, SKYbrary)

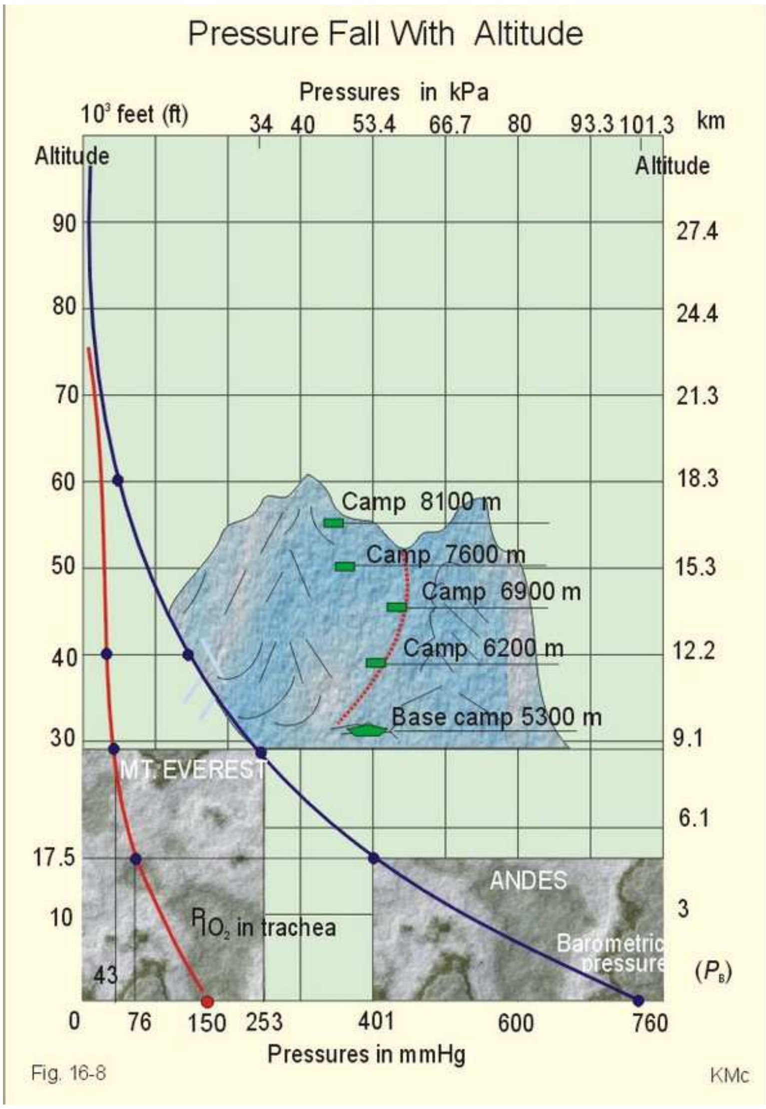
Fall of temperature with altitude

Under the ISA temperature at sea level is assumed to be 15 degrees C and decreases at a constant rate of 1.98 degrees C per 1000 ft up to 36089ft standard tropopause, above which the temperature remains constant at -56.5 degrees C.

Fall of pressure and density with altitude

The weight of air above a surface produces a pressure on that surface- i.e. a force of so many pounds per square inch of that surface. At sea level, the pressure is 29.92 inches of mercury (1013.25 hPa). This is also known as 'one atmosphere'. As ascend is made in the atmosphere, the weight of air above us decreases and pressure will be lower. The rate at which pressure decreases with altitude is greater initially than at higher altitudes. (Kermode, 2006, National Physical Laboratories)

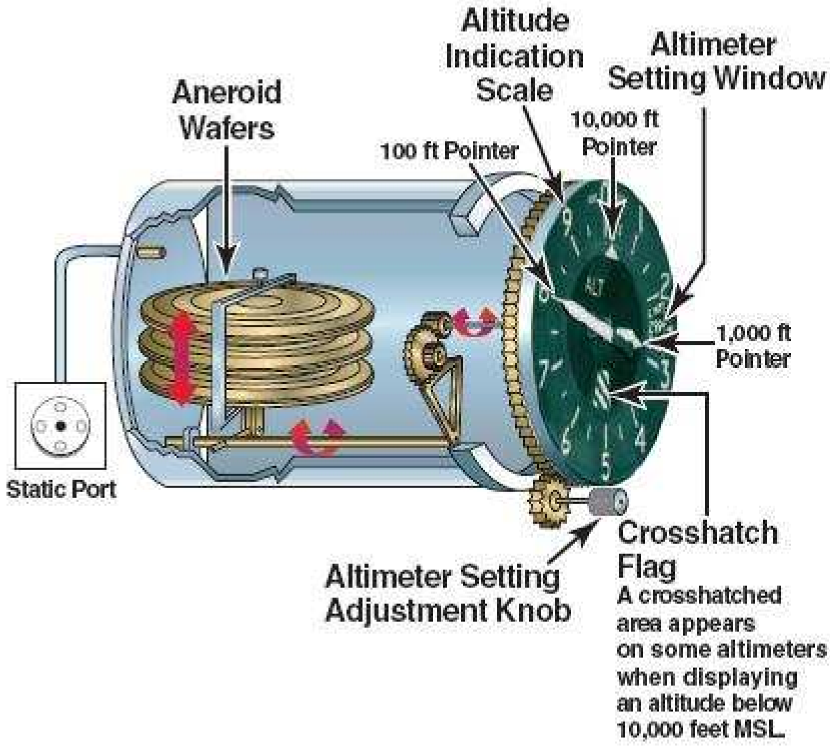
Figure 3: Decrease of pressure with altitude (wikipedia)



This is because air is compressible. Nearer to the surface of the earth, air is compressed by the air above it. Therefore with increasing altitude, the pressure becomes less. Density also falls with increasing altitude but not as rapidly as pressure. (Kermode, 2006)

HOW DOES THE ALTIMETER WORK?

Figure 4: The Mechanism



A pressure altimeter detects changes in atmospheric pressure as ascent or descend is made. Its mechanism is housed in an air tight case which is connected to the static line. As pressure falls, the aneroid wafers in the altimeter expand. Its small linear motion is transmitted to the sector gear, via the rocking shaft and a connecting link which move the gears and pointers to show the altitude. 3 aneroid capsules are used to give the altimeter more sensitivity. (Kermode, 2006, Pallett, 1996)

Aneroid wafers are the pressure sensing element of the altimeter. They are formed by joining corrugated metal discs together, evacuating them close to vacuum and sealing them off. The characteristic of the capsule is dependent on the number and depth of its corrugations, thickness, area, and elasticity of the material. Under normal atmospheric conditions, capsules have the tendency to collapse. The U-bracket which opens outward provides the spring tension to prevent the capsules from collapsing. A state of equilibrium is thus obtained. (Pallett, 1996)

When the atmospheric pressure decreases, the force that pushes on the aneroid wafers is lowered, but the spring tension of the does not change. This allows them to open out further. The reverse happens when atmospheric pressure rises. The resulting linear motion from expansion and contraction of the capsule is extremely small. (Pallett, 1996)

TEMPERATURE COMPENSATION

In addition to preventing the aneroid wafers from collapsing under normal atmospheric conditions, the bimetallic U-bracket also acts as a temperature compensating device.

The temperature coefficient of the altimeter is largely determined by the elasticity of the aneroid material which varies with temperature. Elasticity is the property of a material to return to its original dimension and shape when the applied force is removed. (Kermode, 2006, Chris, Luebkeman & Peting, 1996)

For example should the temperature at sea level decreases, the altimeter will over-read. This increases the elasticity of the aneroid causing it to expand more. With increasing altitude, the same will occur but coupled with the decrease in air pressure, the capsule deflection will get progressively greater, hence the errors. The bimetallic U-shaped bracket bends inwards to oppose this extra expansion, thus cancelling out the error. The opposite occurs when ambient temperature is higher than the standard conditions. (Pallett, 1996)

ALTIMETER ERRORS

An altimeter will only read correctly under conditions for which it is calibrated temperature; Standard Atmospheric Conditions which assumes a temperature lapse rate of 1.98^{o}C for every 1000ft increase in altitude and a sea level pressure of 1013.25 hPa. In this case an altimeter will show the pressure altitude. Under non-standard conditions, an altimeter reading will be in error and will instead show indicated altitude. (Kermode, 2006, Pallett, 1996)

Pressure Errors

As altimeters are barometric instruments, its accuracy will be affected by changes in the ambient pressure. If an aircraft in flight flies into a region where the ambient pressure is higher than what it should for that altitude under standard conditions, the altimeter will under-read if no corrections are made. In regions where pressure is lower than the ISA for that altitude, the altimeter over-reads. It is also possible when descending through a region with decreasing atmospheric pressure the altimeter will continue to show the same altitude. (Kermode, 2006, Pallett, 1996)

Temperature Errors

In practice, there are considerable deviations in temperature lapse rate. Since air pressure is dependent on both height and temperature, a discrepancy known as temperature occurs. Variations in temperature affect the air density and therefore the weight and pressure. Pressure decreases more rapidly in cold air than in warm air. If an aircraft flies into a region where the temperature is lower than what it should be under the ISA, the altimeter will read higher, which is dangerous. In a region where ambient temperature is higher than the standard for that altitude, the altimeter will under-read. (Kermode, 2006, Pallett, 1996)

See online simulator at: http://www.luizmonteiro.com/Learning_Alt_Errors_Sim.aspx

Adjustment Device

The barometric scale adjustment knob is linked to a scale or counter calibrated in hPa or inches of mercury and the indicating mechanism in a way that the correct pressure/height relationship is achieved. This enables compensation for altitude errors due to changes in the atmospheric pressure to be achieved by setting the altimeter to the prevailing pressure on ground so that pointers show zero. (Pallett, 1996)

OTHER ERRORS

Blockage Errors

This occurs when the static source becomes blocked for example by ice. Such an altimeter will cease to detect changes in the static pressure and continuously show the reading at which blockage occurred. (Harris, 2004)

Instrument Errors

As in other mechanical devices, the altimeter is manufactured with small tolerances in all its moving parts and these introduce minor inaccuracies in its performance. Instrument errors are usually insignificant. (Harris, 2004)

Lag Error

This is caused by a delay between changes in atmospheric pressure and the response of the aneroid, which results in movement of the pointer lagging behind a change in altitude. Its magnitude is determined by the rate at which atmospheric pressure changes. (Harris, 2004)

ALTIMETER SETTING

'Q' Code for Altimeter Setting

Setting an altimeter to the pressure prevailing at an airfield or at various flight levels is part of the flight operating techniques and is essential for maintaining sufficient separation between aircraft and sufficient terrain clearance during take-off and landing.

In order to set the altimeter, pilots require observed meteorological data which are transmitted from ground control stations on request. The request and transmission are adopted universally and is part of ICAO 'Q' Code of communication. The three letter code groups used in connections with altimeter settings are: (Pallett, 1996)

QNE

Setting the pressure scale to the **standard sea level pressure of 1013.25 mb** (29.92 in Hg) to make the altimeter read airfield elevation, and flight level **(Pressure Altitude).**

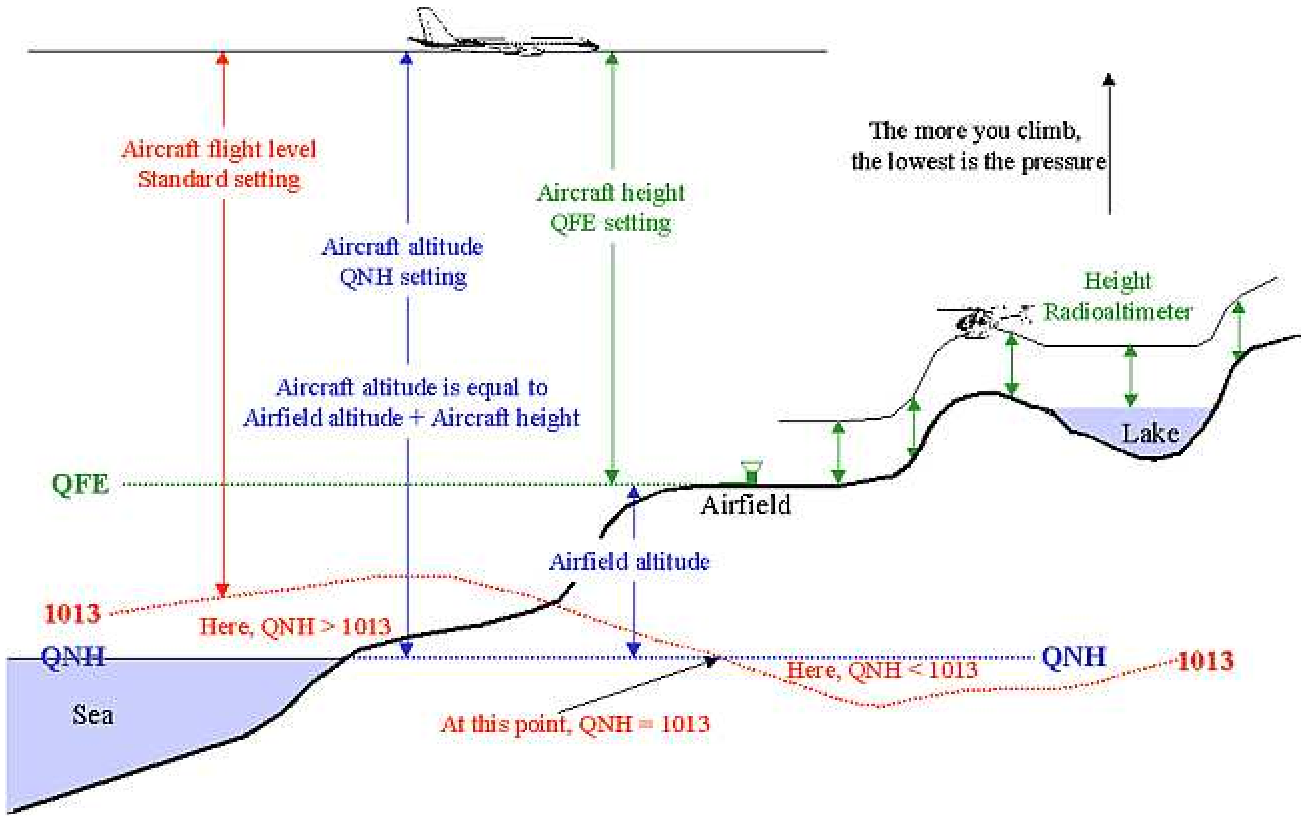
QFE

Setting the pressure scale of the altimeter to the prevailing pressure at a selected place, for example the touch down point of the runway. Prior to take-off and on landing, the altimeter reads zero.

QHN

Setting the pressure scale so that the altimeter **reads the height of the airfield above sea level** (elevation of the ground) on take-off and landing.

Figure 5: Difference between QFE and QNH Setting (academy.ivao.aero)



ACCIDENTS

Numerous accidents have been the result of pilots misreading the instrument. In a 1965 study done by Naval Research Laboratory, it was found that the 3 point altimeter was most prone to misreading and pilots took longer to decipher the correct reading. On 16 August 1965, a United Airlines Flight 389 crashed into lake Michigan while descending. The probable cause was pilots misreading the altimeter by 10,000 ft.
See more about the accident at: http://en.wikipedia.org/wiki/United_Airlines_Flight_389

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