DOCUMENT

GSM-G-CPL.016

DOCUMENT TITLE

FLIGHT INSTRUMENTS

CHAPTER 2 – THE ALTIMETER

Version 1.0

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THE ALTIMETER

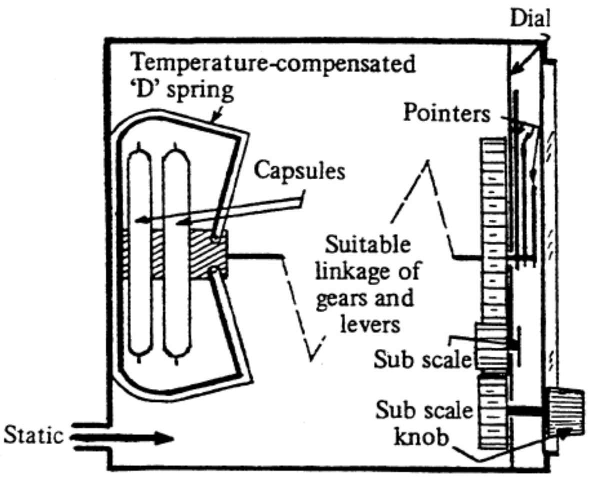
Altitude is defined as the vertical distance measured above sea level. There is no simple accurate way of measuring vertical distance to an airborne aircraft. Modern radar and optical sensors can be used to measure height (vertical distance above ground level), however these sensors are heavy and costly. Using static pressure which decreases with height is a practical way of generating an indication of height or altitude for all aircraft. This method is not perfect and some corrections need to be made.

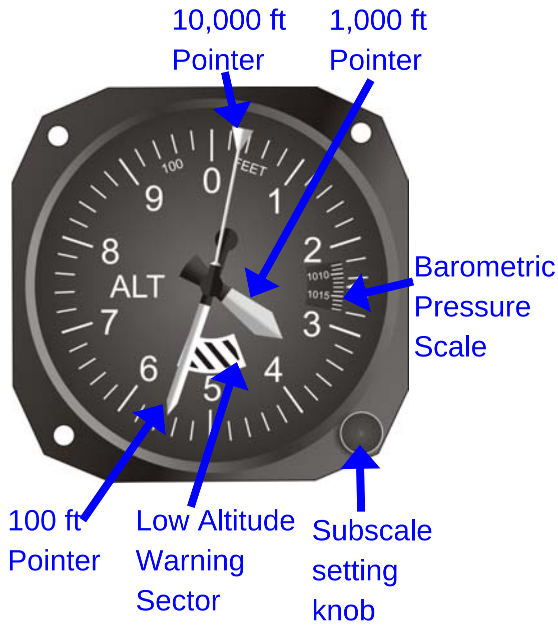
A barometer is a pressure measuring device. A barometer responds to changes in the earth's atmospheric pressure (static) to indicate the high and low pressures as local climatic conditions change. A barometer, kept in one place (a set distance above sea level), will indicate local pressure. The sensing device in a barometer is an aneroid capsule. This capsule is made of metal and is designed to be flexible. It is partially evacuated and prevented from collapsing by a spring. This sealed capsule will respond to any change in atmospheric pressure by expanding or contracting.

Note : A barometer senses pressure at a fixed elevation and is calibrated in hectopascals (1 hPa = 1 mb)

An altimeter is very similar to a aneroid barometer. The pressure sensing element is a partially evacuated metal capsule placed in an instrument casing which is completely sealed and connected to the static system. As the aircraft climbs and descends, the static pressure acting on the capsule varies resulting in expansion and contraction of the capsule which, when relayed by the mechanism, causes a change in the indication of height.

The altimeter is fitted with a knob which allows the pilot to set a datum pressure (reference pressure) on a subscale. The reference datum usually used is 'mean sea level', which is achieved by setting the QNH on the subscale. At sea level with the correct QNH set, the altimeter should indicate zero feet.





Note: The temperature compensated D spring corrects for the effects of variation in cockpit or flight-deck temperature on the mechanism of the altimeter.

PRINCIPLE OF OPERATION

- measures static pressure.

- indicates vertical distance in feet from a selected datum.
  * altitude (above mean sea level) on QNH.
  * height (above AD elevation) on QFE.
  * flight level (pressure height) above 1013 hPa.

- Capsule movement is magnified by gears and levers to position pointers.

- In the UK the range of sub-scale settings is 800 to 1050 hPa

- The altimeter is calibrated to read correctly in ISA conditions.

ACCURACY

A typical mechanical pressure altimeter of the sensitive type will be accurate to:

± 50 feet	at 0 feet
± 175 feet	at 10,000 feet
± 600 feet	at 40,000 feet

It should be noted that all pressure altimeters are much less accurate at high altitude. This is because at high altitude, the pressure change equivalent to a given height change is much less than it would be at low altitude. Since friction and other mechanical imperfections within the instrument remain constant, the altimeter becomes less responsive, less accurate and more susceptible to lag as altitude increases.

CAUSES OF ERROR IN ALTIMETER READINGS

BAROMETRIC ERROR:

This is the error induced in an altimeter when atmospheric pressure at sea level differs from ISA. The correct setting of the barometric subscale (QNH) minimises the error.

TEMPERATURE ERROR*:*

Is the error induced in an altimeter when the temperature differs from ISA.

NB: There is no adjustment available and this error will need consideration if the pressure altimeter is used for terrain clearance.

POSITION ERROR:

This error occurs because of static system errors related to airflow sampling. It is affected by the position of the static pressure sensors. Errors vary with speed and attitude and include manoeuvre induced errors.

INSTRUMENT ERROR*:*

These errors are due to small manufacturing imperfections and the large mechanical amplification necessary for small sensed movements. Instrument error increases with altitude as the capsule movement is small (pressure change for a given height at altitude is less than the change at sea level).

LAG ERROR:

The response of the capsule and linkage is not instantaneous and so the altimeter reading lags when height is increased or decreased rapidly. This is dangerous during a rapid descent when the altimeter will over-read due to lag.

BLOCKAGES:

If a blockage of the static system occurs the altimeter will not indicate any further change of height, ie. the altimeter will continue to indicate the altitude at which the blockage occurred. A partial blockage will cause significant lag in the altimeter.

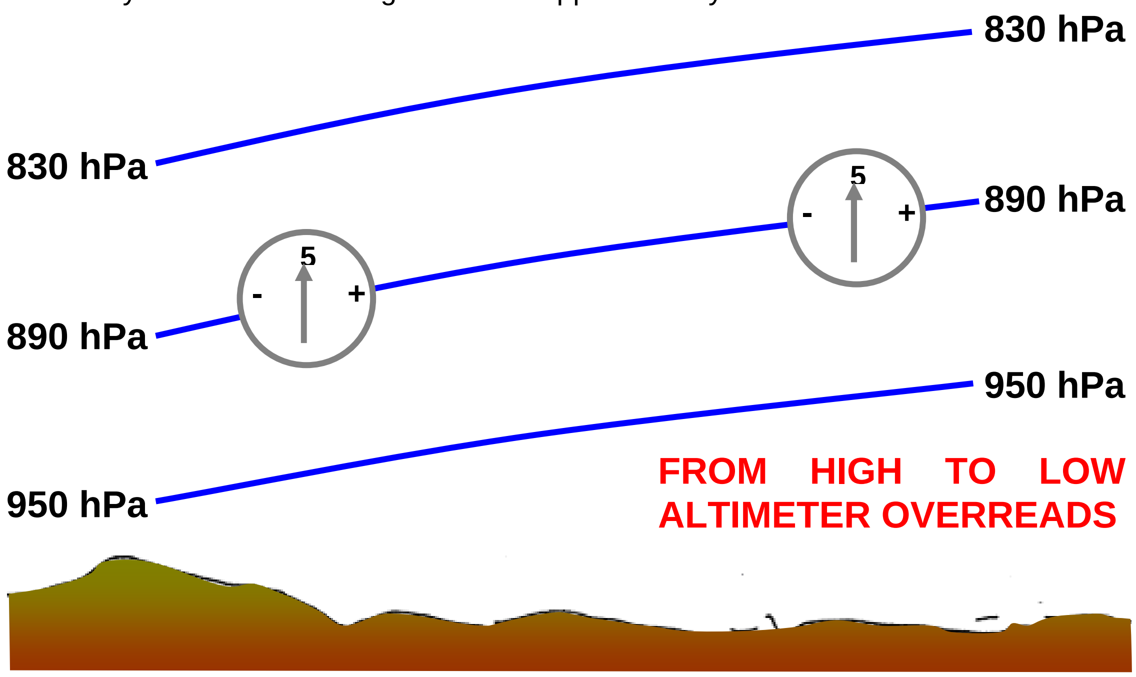
Note : Errors caused by blockages are usually corrected by selecting ALTERNATE STATIC ON.

THE EFFECT OF BAROMETRIC ERROR

If flying from a high to a low pressure area on a constant altimeter setting, the altimeter will 'over read'. In the illustration below, the indicated altitude is greater than the true altitude. Conversely when flying from a low to a high pressure area, the altimeter will under-read.

Area (Regional) QNH zones can have a significant difference between adjacent zones.

This means if the new QNH is not set a large error can occur. It should be noted that a 1mb inaccuracy in sub-scale setting will cause approximately a 30 foot error in altimeter reading.

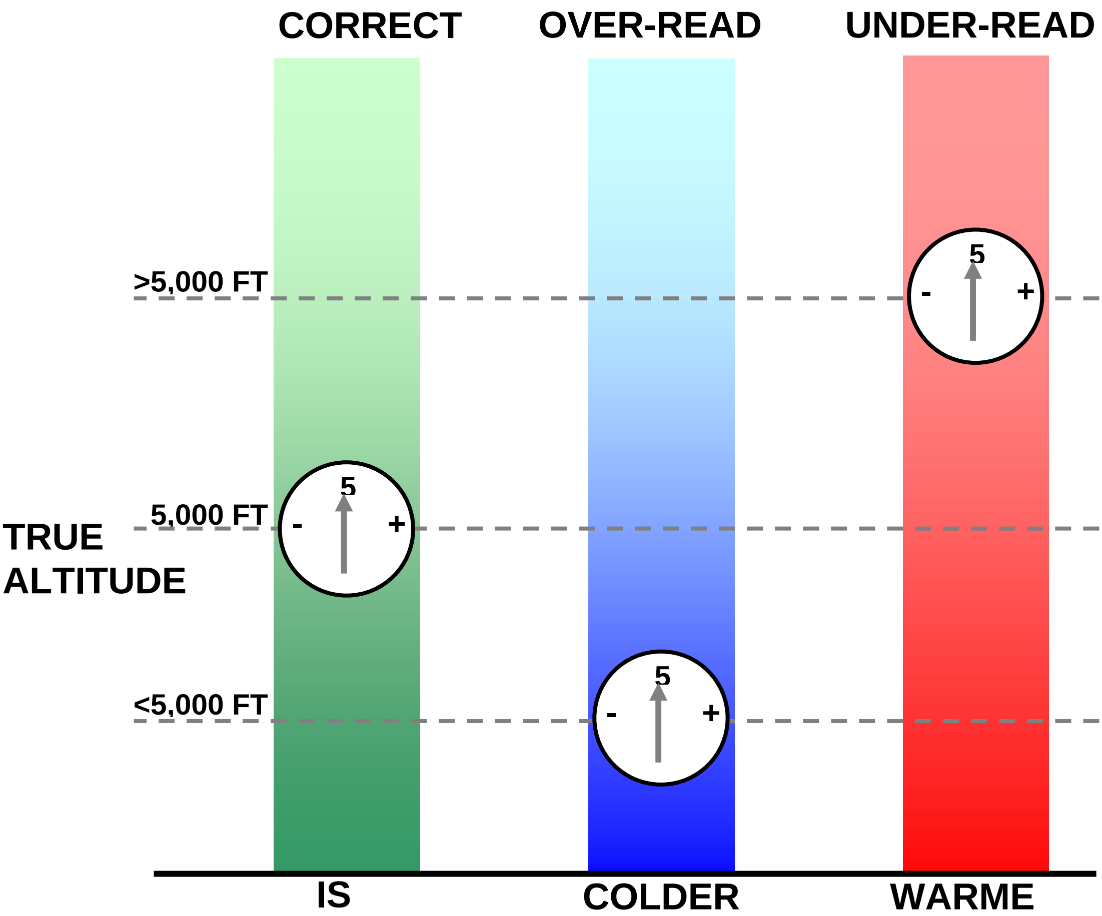


THE EFFECT OF TEMPERATURE ERROR

Temperature error, like barometric error, arises whenever the atmospheric conditions differ from those assumed by the standard atmosphere. If the mean temperature in the column of air below the aircraft does not coincide with the ISA model, the indicated height will be incorrect.

Temperature affects air density and so affects the pressure lapse rate. The result is that the pressure at a given level in a column of cold air is less than the pressure at the same level in a column of warm air. The altimeter therefore over-reads when the temperature conditions are colder than ISA and under-reads when temperatures are warmer than ISA.

In the diagram below, the aircraft is flying at an indicated height of 5,000 feet. Flying in conditions colder than ISA will result in an over read and warmer than ISA will result in an under read.



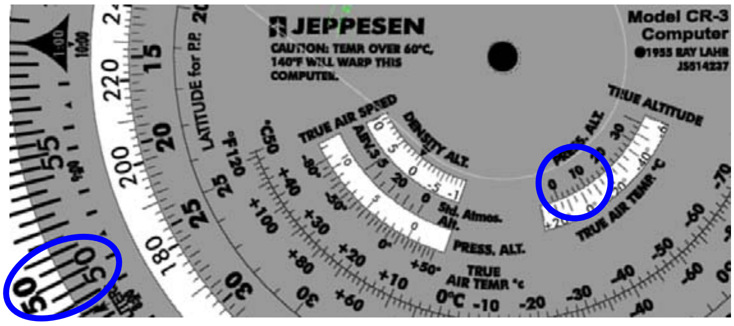
Note:

- Temperature is the most significant error of the altimeter and is commonly as much as 500 feet in 10,000 feet.
- Temperature error is zero at the pressure datum and increases with increase in height.
- Temperature error has little effect on the clearance between aircraft flying at different flight levels. A flight level is a constant pressure level, based on the standard pressure setting of 1013mb. It is not a constant altitude, and so continues to be shown correctly.

CALCULATING TEMPERATURE ERROR

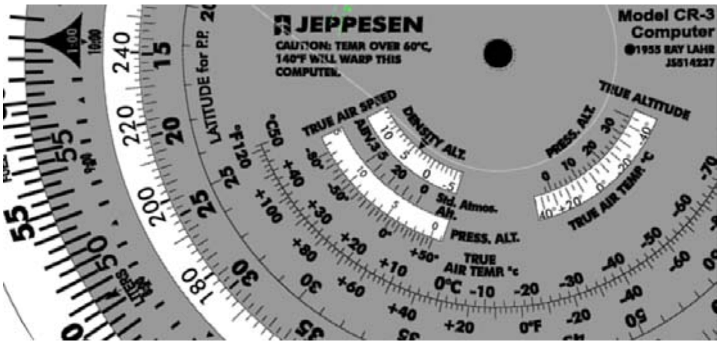
The Jeppesen Computer can help you to understand Temperature Error and allows you to calculate <u>true altitude</u>.

Locate - the small 'True Altitude Window'. Set Pressure Altitude of 0 ft and 15°C. (or any other altitude and its ISA temperature). Against Calibrated Altitude (inside grey scale) 5,000'. Read True Altitude (outside white scale) 5,000'.



Note: As the altimeter is calibrated to ISA conditions, the indicated altitude (calibrated) and the true altitude are the same.

Now, against a pressure altitude of zero feet (sea level) set 30°C (ISA+15). Using an indicated (calibrated) altitude of 5,000 feet read off the True Altitude (≈ 5,300). The indicated altitude is less than the True Altitude; the altimeter is therefore under-reading.



OROGRAPHIC CONSIDERATIONS

The pressure altimeter is subject to another error related to pressure variation. Because of the mechanical effects of strong winds in mountainous areas, pressure in the lee of mountains is reduced causing the altimeter to indicate a higher than true altitude. While an over-reading altimeter is already a dangerous situation, the danger is compounded for light aircraft. When travelling into wind on the lee-side of a mountain, the over-reading altimeter may delay pilot recognition of the problem and down drafts may exceed the climb capability of the aircraft.

ALTIMETER SERVICEABILITY

1. In Australia with QNH set the altimeter must read site elevation
   - within 2 hPa ($\pm$ 60 ft) for IFR aircraft.
   - within 3 hPa ($\pm$ 90 ft) for VFR aircraft.

2. The subscale must be functional.

3. Glass clean, no damage to instrument.

ALTIMETER DRIFT

A brief consideration of the meteorological pressure patterns will show that when approaching a Low or departing a High in the Southern Hemisphere the aircraft will always drift left. Consequently, when subject to left drift the High Low High rule applies; the altimeter over-reads (the aircraft true altitude is less than the indicated altitude). When departing a Low or approaching a High the aircraft will drift right and the altimeter will under-read. These errors in the altimeter are effectively eliminated if the sub-scale setting is regularly updated to show the correct QNH.

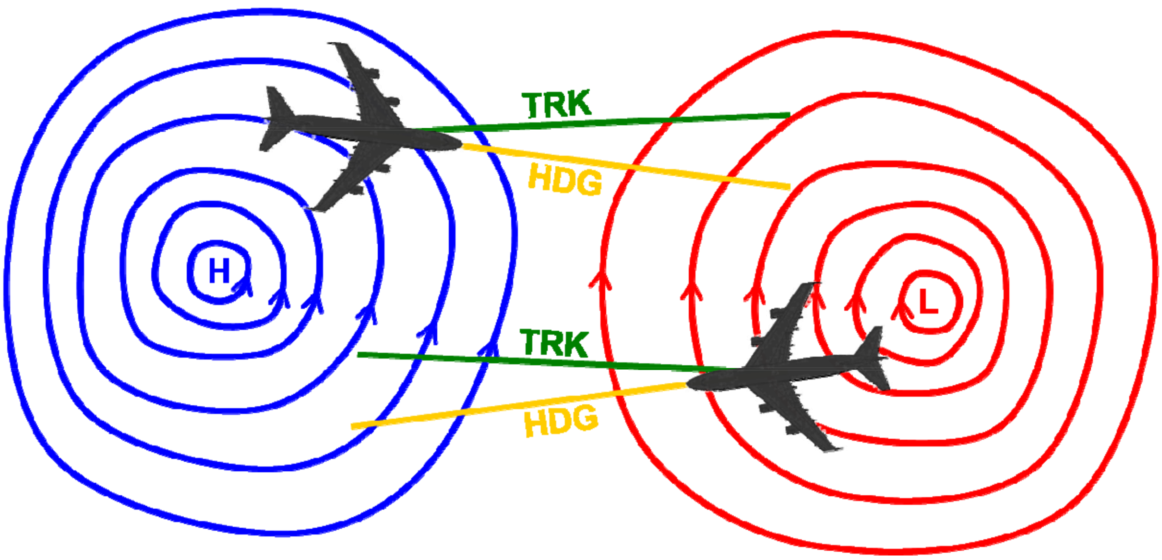


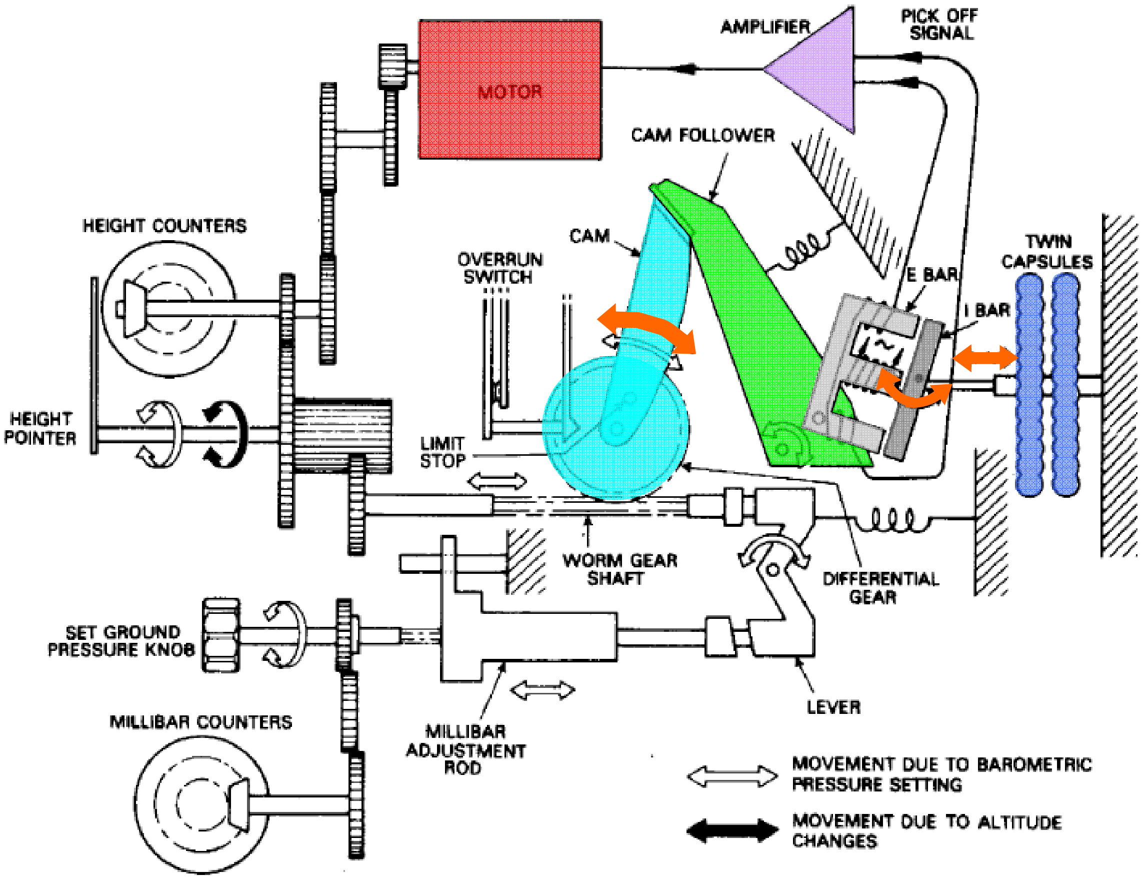
Diagram : Altimeter Drift - Southern Hemisphere *(*Opposite results will occur in the Northern Hemisphere)

SERVO ASSISTED ALTIMETERS

The basic pressure altimeter with its accuracy and performance limitation and its 'stand alone' capability has its place in aviation. The servo assisted altimeter retains the pressure sensing principle (partially evacuated capsules), however the transmission system now uses an accurate electro-magnetic sensor and the counters and pointers are powered by an electric motor (servo).

PRINCIPLE OF OPERATION

Expansion and contraction of the capsules moves a balanced I bar. This movement changes the air gap between the I and E bar so affecting the magnetic field induced by the A.C. exciter current in the upper and lower spokes of the E bar. Assuming the I bar has moved to a position which is not symmetrical with the E bar, a current will flow in the pick-off winding. This current flow is amplified, rectified and phase-detected at the amplifier and then passes as D.C. to the servo motor. The motor turns to change the altimeter reading as registered by the counters and pointer and at the same time moves the E bar, via the cam, so that it follows the movement of the I bar. When E and I bars are again symmetrical, current flow (and the motor) will stop. Note that the shape of the cam allows for the non-linear relationship between pressure and height in the standard atmosphere.



SERVO ALTIMETER - SUMMARY

1. Very sensitive because of inductive pick-off sensing. This is particularly an advantage at high altitude when the rate of pressure change is low.

2. Accurately ± 1 hPa (mb) over entire range.
   i.e. at sea level ± 30 ft.
   at FL200 ± 50 ft.
   a FL400 ± 100 ft.

3. Lag errors virtually eliminated.

4. Electrical system lends itself to
   - digital presentation.
   - SSR encoding.
   - Altitude alerting systems.

THE HEIGHT ENCODING ALTIMETER

Some altimeters are equipped with altitude encoders (or digitizers) which provide a coded height output. When transmitted via a remote transponder, the coded output enables the pressure altitude sensed by the capsules to be monitored by ATC on the ground. It should be noted that the coded output is always referenced to 1013mb (hPa) and so is independent of the pilot's sub-scale setting. Further information about transponders is provided in the Radio Navigation Aids notes.