PRINCIPLE OF OPERATION

The pressure altimeter is a simple, reliable, pressure gauge calibrated to indicate height. The pressure at a point depends on the weight of the column of air which extends vertically upwards from the point to the outer limit of the atmosphere.

The higher an aircraft is flying, the shorter is the column of air above it and consequently the lower is the atmospheric pressure at the aircraft.

In other words, the greater the height, the lower the pressure, and by measuring the pressure the altimeter measures height.

Unfortunately, the relationship between pressure and height is not a linear one, so that calibration of the altimeter scale is not a simple matter.

The situation is further complicated by high and low pressure weather systems which produce pressure differences in the horizontal plane. Furthermore, the temperature of the air at the surface and the temperature lapse rate in the air above vary considerably; this affects pressure.

The theory of the atmosphere is explained fully in book 9 - Meteorology.

CALIBRATION

With all these variables it becomes necessary to assume certain average or 'standard' conditions, base the calibration formulae on these, and then apply corrections appropriate to the deviations from standard conditions which occur with position and time.

The conditions used for calibration are usually those assumed for the:

International Standard Atmosphere
ISA

The relevant assumptions are:

At mean Sea Level
Pressure 1013.25 millibars Temperature +15°C Density 1225gm/m^3

From MSL up to 11 km (36,090 feet)
Temperature falling at 6.5°C per km (1.98°C/1000 feet)

From 11 km to 20 km (65,617 feet)
A constant temperature of - 56.5°C

From 20 km to 32 km (104, 987 feet)
Temperature rising at 1°C per km (0.3°/1000 feet).

With these assumptions, the pressure corresponding to any given level in the ISA can be calculated from the calibration formulae.

Graphs or tables can be produced showing height in terms of pressure under standard conditions. These tables can be used for the manufacturer's calibration of the altimeter scale.

Basically, the laboratory calibration consists of applying a series of pressures to the altimeter and checking that the instrument indicates the respective levels which correspond to these pressures in the ISA.

Any discrepancies, if within certain agreed tolerances, would be listed over the operating height ranges as instrument errors. (The calibration is carried out with increasing and decreasing readings so that the amount of lag at calibration conditions can be determined).

Note: 1 *The Pressure Altimeter is calibrated to give a Linear Presentation of the Non-linear Atmospheric distribution. This is achieved by the use of a variable magnification lever system and the dynamic design of the capsules.*

Note 2: *Temperature compensation is achieved by the use of a bi-metal compensator connected in the lever/linkage system.*

Note 3: *1013.25 mb/hPa = 29.92"Hg = 14.7 psi*

SIMPLE ALTIMETER

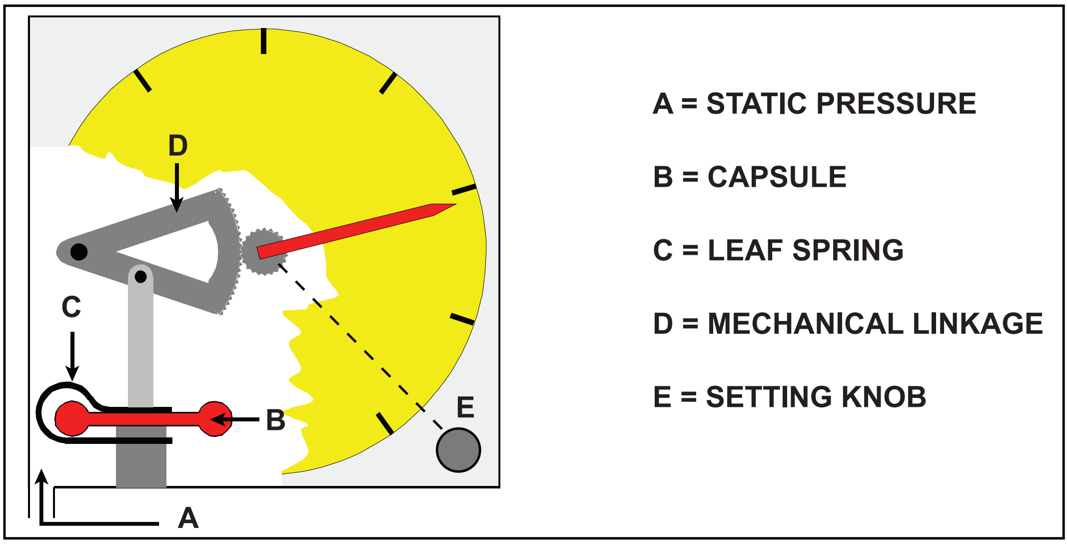

Figure 5.1 Simple Altimeter

Static pressure is fed into the case of the instrument from the static source. As height increases, static pressure decreases and the capsule expands under the control of a leaf spring. A mechanical linkage magnifies the capsule expansion and converts it to a rotational movement of a single pointer over the height scale. The linkage incorporates a temperature-compensating device to minimise errors caused by expansion and contraction of the linkage and changes in spring tension due to fluctuations in the temperature of the mechanism.

Figure 5.1. shows the basic linkage, but the actual arrangements are much more complex.

The simple altimeter has a setting knob which is geared to the pointer. With this knob the pointer can be set to read zero with the aircraft on the ground so that when airborne the altimeter indicates approximate height above aerodrome level. Alternatively the pointer can be set (before flight) to the aerodrome elevation so that when airborne the instrument shows approximate height above mean sea level.

SENSITIVE ALTIMETER

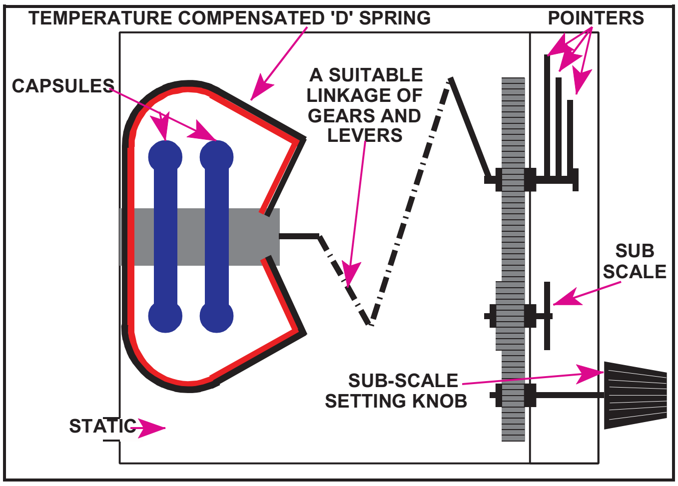

Figure 5.2 Sensitive Altimeter

The Single Pointer Single Altimeter was not accurate enough, and was developed into the Sensitive Altimeter illustrated in Figure 5.2.

The principle of operation is similar to that of the simple altimeter but there are the following refinements:-

- A bank of two or three capsules gives the increased movement necessary to drive three pointers. These are geared 100:10:1, the smallest indicating 100,000 feet per revolution, the next 10,000 feet per revolution and the largest 1,000 feet per revolution.

- Jewelled bearings are fitted, reducing friction and the associated lag in indications.

Note: *Some altimeter systems employ "Knocking / Vibrating" devices to help overcome initial inertia of the internal gear train when transmitting movement from the capsules to the pointers.*

- A variable datum mechanism is built in. This, with the aid of a setting knob, enables the instrument to be set to indicate height above any desired pressure datum.

The variable datum mechanism is used as follows:-

The pilot turns the knob until the desired pressure level (say, 1005 mb. appears on a pressure sub-scale on the face of the instrument.

As he turns the knob, the height pointers rotate until, when the procedure is completed with the sub-scale showing the desired 1005, the altimeter indicates the aircraft's height above this pressure level.

If for instance the aerodrome level pressure happened to be 1005 mb, the altimeter would be reading height above the aerodrome (and the pilot would have set a 'QFE' of 1005 on the sub-scale). Further details of the procedural uses of the pressure sub-scale are given later in this chapter. The sub-scale setting only changes when the pilot turns the knob. A change in altitude or surface pressure has no direct effect on the reading of the sub-scale. As the pilot alters the sub-scale setting, the altimeter pointers move, but the design of the mechanism is such that the reverse does not apply (for example, during a climb, the pointers rotate but the sub-scale setting remains unchanged). British altimeters have a sub-scale setting range between 800 to 1050 millibars.

READING ACCURACY

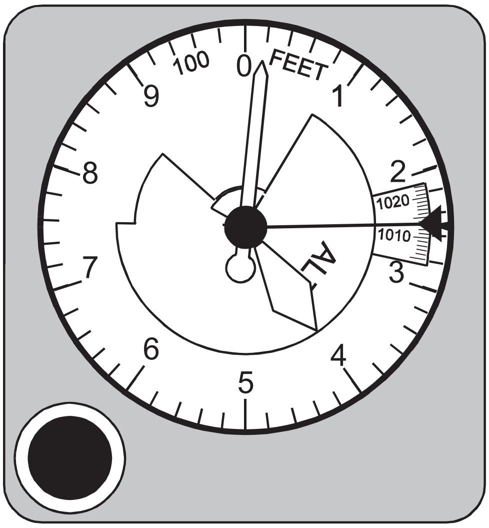

Figure 5.3 Three Pointer Altimeter Indicating 24,020 ft

The simple altimeter is not sensitive, recording perhaps 20,000ft for each revolution of its single pointer. The three-pointer instrument gives a much more sensitive indication of height and change of height but suffers from the severe disadvantage that it can be easily misread.

It is not difficult for the pilot to make a reading error of 10,000ft, particularly during a rapid descent under difficult conditions with a high flight-deck work-load.

Accidents have occurred as a result of such misreading. Various modifications to the pointers and warning systems have been tried with the object of preventing this error, including a striped warning sector which appears as the aircraft descends through the 16,000 foot level.

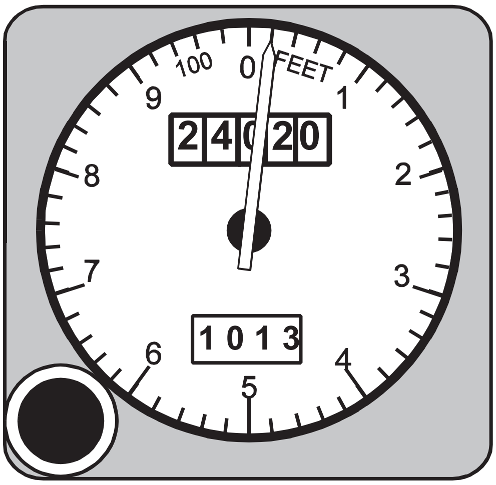

Figure 5.4 Counter / Pointer Altimeter

The greatest advance has been the introduction of the counter-pointer altimeter, illustrated in Figure 5.4., which gives a much more positive indication than the three-pointer dial drawn in Figure 5.3.

With further reference to Figure 5.4., it will be realised that though the digital counters give an unambiguous indication of the aircraft's height, they give a relatively poor display of the rate of change of height.

For this reason the instrument also has a single pointer which makes one revolution per 1000 feet, giving the clear indication of change of height which is extremely important to the pilot, particularly on the final approach in instrument conditions.

EXAMPLES OF ALTIMETERS

A Sensitive Altimeter Reading 260ft

Altimeter Reading
12,8500 ft or
3,917 m

Electronic Display fitted to a Boeing 737

Fig 5.5 Altimeter Types

INTRODUCTION

The Flight Director System (FDS) was originally developed as an aid used by the pilot during landing. It gave a pilot the ability to concentrate on fewer instruments and, as it gave instructions as to attitude and steering, it reduced the workload on the pilot. As autopilots became more advanced the signals produced by the FDS could be coupled to the autopilot allowing it to perform more complex tasks.

With a FDS, information about the attitude, heading and flight-path of an aircraft, can be integrated with navigation information to produce either easy to interpret visual instructions for the pilot and / or input to the autopilot, or both.

To bring the terminology of FDS and autopilot together it is usual to describe the FDS as having 2 "channels". The first channel is the **roll channel**, the second is the **pitch channel**. You will learn more about channels in the autopilot section.

Information for the FDS can come from several possible sources:

- Pitot-Static system or Air Data Computer (ADC).
- VHF Nav receiver allowing input from VOR beacons or ILS.
- Flight Management System, Inertial Navigation / Reference System.

The FDS also requires attitude and directional information. On older, electro-mechanical systems this would come from the Gyro Magnetic Compass and a Vertical Gyro System. More modern aircraft use Inertial Navigation/Reference System (INS / IRS) information in place of a vertical gyro and will be able to feed the navigation data from these systems into the FDS / Autopilot combination.

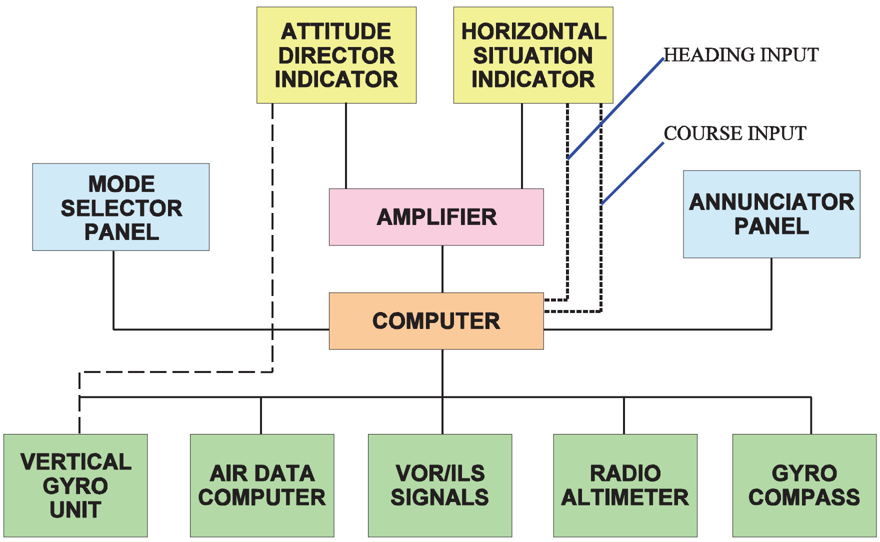

Fig 28.1 A "typical" electro-mechanical Flight Director System

FLIGHT DIRECTOR SYSTEM COMPONENTS

There follows a description of a "typical modern" FDS:

Electronic Attitude Director Indicator (EADI)
This is a fairly standard artificial horizon providing pitch and roll information and gives the Attitude to the name of the instrument. The Director part comes from the instruments ability to display demand information from the Flight director system using Flight Director Command Bars. These come in 2 main forms as shown below:

Both of the indications for these apparently different displays are intuitive and essentially the same in that the pilot is required to "fly to" either the point where the "wires" cross, or the point between the wedges, in order to satisfy the demand from the FDS.

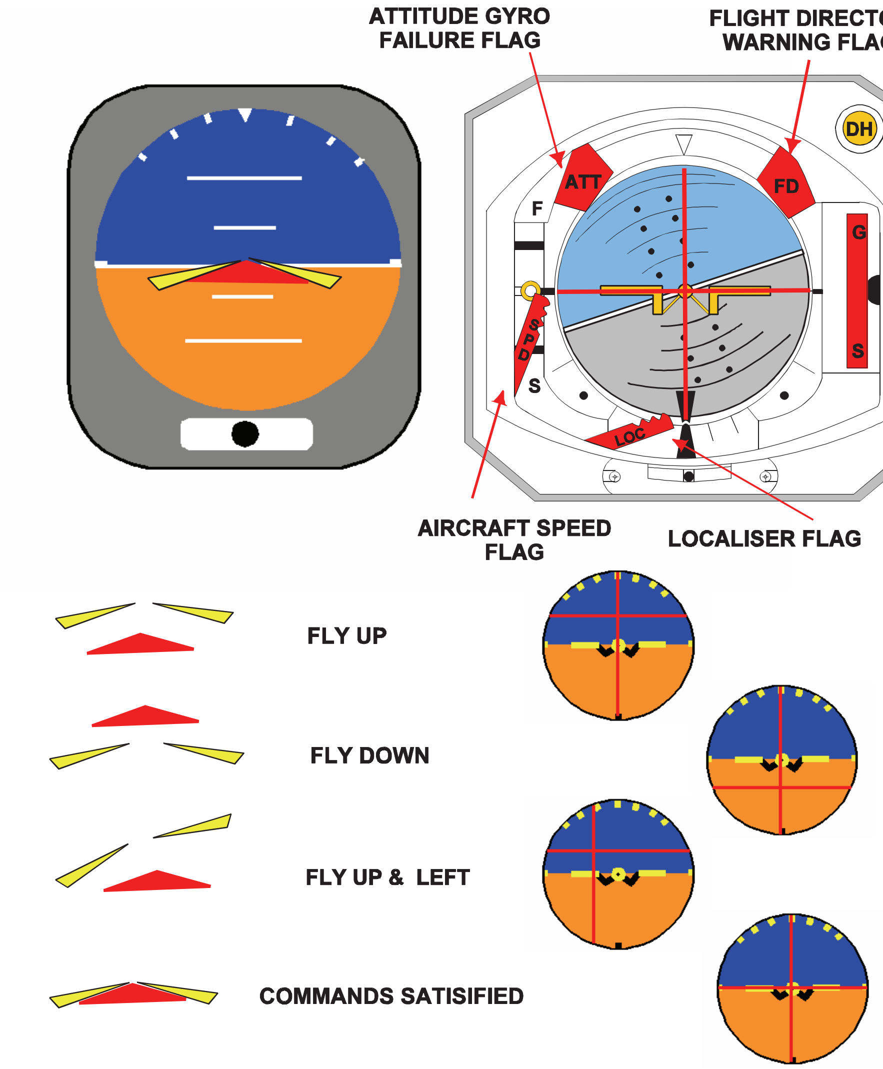

Figure 28.2

Primary Flight Display (PFD)

The PFD is part of an EFIS (Electronic Flight Instrument System) display and brings all of the information required to fly the aircraft onto one display. It has an EADI normally surrounded by speed, altitude, and vertical speed tapes and often a compass display incorporating some minimal navigation information. It also has an area which is used for annunciating flight director, autopilot and auto-throttle modes and status.

Figure 28.3

Electronic Horizontal Situation Indicator (EHSI)

You may already be familiar with the Gyro Magnetic Compass. An HSI is a gyro magnetic compass display with a Course Deviation Indicator (CDI bar), a series of dots representing deviation in degrees (the scale varies with the type of display) a from / to pointer, a selected course window and a DME display of range. A heading bug is also included. In older systems the course selection is done directly on the HSI using an attached knob. The system we will refer to uses a remote centralised FD mode control and AP panel called the Autoflight Mode Control Panel (AMCP or simply MCP). The system we will be referring to also uses a Navigational Display (ND). This, like the PFD, is a more flexible display but is able to show "classical" representations of an HSI.

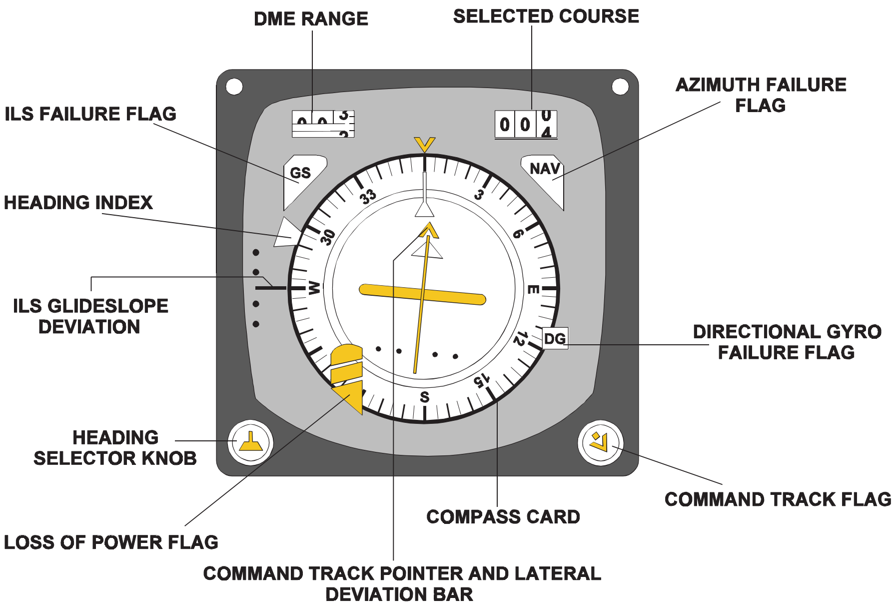

Figure 28.4 HSI Display

Figure 28.5 EHSI