CHAPTER 13

INSTRUMENTS NOTES FOR THE GPL EXAM

The minimum instruments required in a glider are:

- Air Speed Indicator (ASI)
- Altimeter
- Compass
- Radio

1. ALTIMETERS - Different types and how they work.

The loss of atmospheric pressure with height is 1 MB drop per 30 ft increase in height up to 6 000 ft. Above 6 000 ft the increase in height necessary to cause a drop of 1 MB becomes gradually greater. A simple altimeter can be constructed to make use of this relationship. An elastic-metal capsule is connected to a needle on a dial by means of a system of levers and gears. This is known as a simple Altimeter and usually registers to the nearest 200 ft with each thousand foot mark designated by the appropriate figure.

To provide for accurate and sensitive readings for aircraft the sensitive Altimeter was designed. This is accurate to 20 ft. The major difference apparent to the pilot is that it has three pointers. The largest needle makes one revolution for 1 000 ft. The smaller needle makes one revolution for 10 000 ft and the smallest needle makes one revolution for 100 000 ft. This altimeter allows adjustment for changes in atmospheric pressure. Adjustments are made by adjusting the sub-scale. Common settings for the sub-scale are as follows:

QNH: The altimeter reads height above mean sea level.

QFE: The altimeter reads height above ground level of the station giving the QFE reading.

QNE: The sub-scale is set to a pressure of 1013.2 MB resulting in standard altitudes being shown on the altimeter (used for Flight Levels)

Errors present in the Altimeter.

a) **Instrument Error** can be up to ± 50 ft. Any instrument rugged enough to withstand the vibrations in an aircraft is bound to have certain inaccuracies. A certain amount of change in the readings will occur due to expansion and contraction of the capsule.
A rough check on the accuracy can be made by setting QNH. The altimeter should then read airfield elevation.

b) **Position Error.** The altimeter usually gets the surrounding pressure from a static tube which could be positioned in an area of pressure different to atmospheric, e.g. beneath the wing.

c) **Density Error.** The relationship between atmospheric pressure and height is not a linear relationship. Further complication occurs due to changes of temperature and pressure in the atmosphere. If the atmosphere deviates from the standard to which the altimeter was calibrated, variations in readings can be expected. Aircraft should be flown at an adequate clearance above ground to allow for alterations and errors.

d) **Errors due to changes in Atmospheric Pressure.** As the aircraft is flown into regions of different atmospheric pressure, the altimeter will show incorrect heights. This must be corrected by obtaining the pressure during flight and adjusting the sub-scale. Remember **Hi-Low-Hi** - Flying from High Pressure to Low Pressure the altimeter reads High (and vice-versa).

2. AIRSPEED INDICATORS - Different types and how they work

The speed of an aircraft through the air is found by comparing the pressure on the aircraft due to its forward motion (Total Pressure) with the atmospheric pressure outside the aircraft (Static Pressure).

$$P_{static} + P_{pitot} = P_{total}$$

The Total Pressure is obtained by pointing a Pressure or Pitot Tube into the airflow. The pressure realised in this tube is transferred into an elastic-metal capsule contained in the instrument. Atmospheric pressure is read through a Static Tube or a Static Vent. A Static Tube has a closed end facing into the airflow with a series of holes drilled in the side of the tube. A Static Vent is a small flat metal plate with a hole in it situated on the fuselage and connected to the ASI. The static pressure is transmitted by tubes into the case of the ASI.

$$P_{total} - P_{static} = P_{dynamic}$$

Errors present in the ASI.

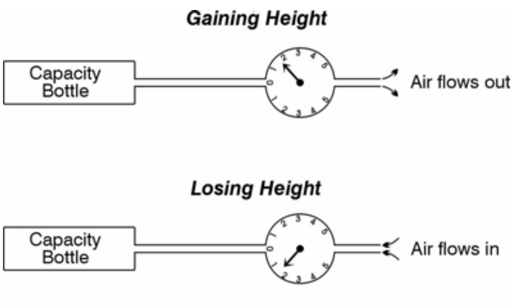
- **Position Error.** The Static Tube is usually placed on the side of the aircraft where the pressure is neither high nor low. The ASI is affected by poor positioning of the Static Tube in a similar manner to the way an altimeter is affected. The placement of the Pitot Tube is not important as it will obtain the same pressure value wherever it is placed. Position Error and Instrument Error are tabulated together on a card fitted alongside the instrument. When applied to Indicated Air Speed these corrections give Rectified Air Speed.
- **Density Error.** The pressure registering in the Pitot Tube will be less for a given airspeed when the atmosphere is less dense. This change of density depends on the height of the aircraft as well as the temperature of the air. A rough rule for correcting for Density Error is to add 1.75% of Rectified

Air Speed per 1 000 ft increase in height from Sea Level.

3. VARIOMETERS - Different types and how they work.

The word "variometer" means "change meter". Different types of variometer measure different changes. All work on the same basic principle. The following are the major types.

a) **Rate of climb indicator** (uncompensated variometer) measures change in aircraft altitude over a time period.

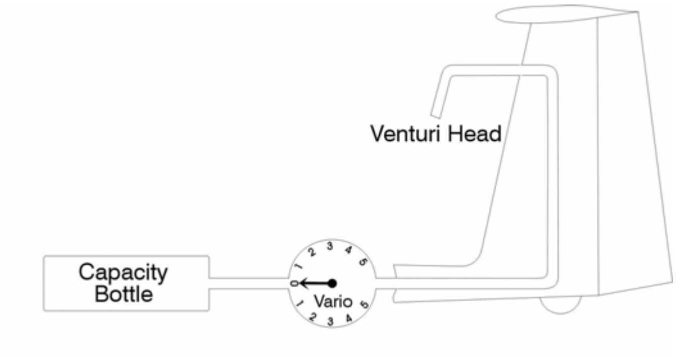


Basic Variometer

The basic variometer consists a vacuum-insulated (with copper wool as heat sink) capacity of about 500 ml connected through a flow sensor to the static pressure system of the glider. When the glider ascends, the decreasing outside pressure causes air to flow out through the sensor. (The flow direction is reversed when descending.) The rate of flow is measured either by measuring the pressure drop as the air passes through an orifice or by the differential cooling of a pair of thermistor beads. All mechanical variometers use the former principle. Any variometer of this type applies a restriction to the flow of air and the reading at any particular instant depends on the history of the outside pressure changes over the previous few seconds. This lag is a disadvantage when thermal-soaring as the reading is about 90 degrees out of phase with the glider. When cruising, however, it helps to smooth out the effect of minor disturbances.

Electrical variometers apply a much smaller constriction to the flow and thus have very little drag. It may even be necessary to incorporate additional electrical or pneumatic damping to prevent excessive oscillations. The output may also be used to drive an audio device.

b) **Total-energy variometer** (TE-compensated variometer) measures changes in the aircraft's total energy over time period.



Total Energy Compensation

A variometer as described in (a) above suffers from a major disadvantage in that, changes in speed affect the variometer reading ("Stick" thermals). This can be largely eliminated by the use of a total- energy system. Total-energy variometers indicate changes in the total energy of the glider, ie both its potential energy (due to altitude) and its kinetic energy (due to

airspeed). Airspeed changes, which are basically changes between kinetic energy and potential energy, are no longer indicated. Due to its insensitivity to airspeed changes, the TE variometer is suitable for use with a MacCready speed ring.

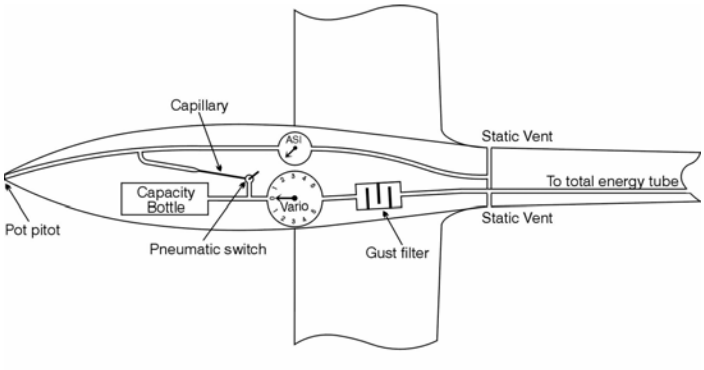
$$E_{total} = E_{kinetic} - E_{potential}$$

Suction can be applied to the static pressure side of the instrument providing a pressure of $P_{static} - P_{dynamic}$. This is a "negative" pressure. The venturi has a value of -1 and causes a static pressure reduction equal to the increase caused by pitot pressure. The suction needed to produce the total-energy effect can be obtained by bulges in the fuselage, a small venturi or by the "Brunswick" (Braunschweig) tube. To make the venturi insensitive to yaw an external ring is placed around the outlet. Insensitivity to yaw is important and Brunswick tubes should be mounted in a region where the local flow is unlikely to be disturbed by adjacent parts of the glider. The Brunswick tubes or venturi are reasonably accurate and consistent at all heights; however are prone to icing and water ingress.

An alternative to the use of suction is to connect a pitot through a diaphragm to the capacity side of the variometer circuit. The effect of this is that the volume of the capacity is varied by the pitot pressure. The disadvantages of this system are that it is only accurate at one height, it is difficult to calibrate and adjust and the calibration may

change with age due to the stiffness of the diaphragm.

c) **Netto variometer** (Total Energy compensated variometer) measures lift and sink of airmass rather than glider. This is sometimes referred to as an “Airman's Vario”.



Netto Variometer

In order to achieve a "net" indication, the always-present polar sink of the glider must be "compensated out" of the indication. A capillary is connected to the capacity side of the instrument which allows just enough air from P_{total} to bleed into the capacity. The capillary needs to be accurately calibrated. It will be different for gliders with different polars and is also dependent on the size of the capacity.

Netto variometers are calibrated based on the straight flight polar and can only be used in yaw-free straight flight.

d) **Speed-to-fly variometer** measures for which expected climb rate the current airspeed is optimum.

The construction of this is the same as a netto variometer. However, the capillary is calibrated differently.

4. BAROGRAPHS - Different types and how they work.

A barograph is an aneroid barometer which records its reading on a chart wrapped around a rotating drum. The mechanism is usually clockwork. The mechanism must work at all altitudes and at the lowest ambient temperatures likely to be encountered. The record may be made in various ways:

- Ink on paper.
- A scratch made by a fine stylus on smoked paper, smoked aluminium foil or a specially coated foil
- Small holes pricked in a paper chart at frequent intervals

Ink on paper has the disadvantage as the friction is high and it can be messy to work with. The ink needs to be a non-freezing type.
Using a stylus which just touches the chart reduces the friction, but a smoked surface is messy to prepare and is easily spoiled by handling.
The system of pricking has the advantage that the effective friction is virtually zero.

Barographs should be calibrated every year. For record and badge flights the barograph must have been calibrated during the 12 months prior to the flight or within one month following. For altitude flights it must be always calibrated within the month following the flight.

A barograph proves two items:

- Maximum height
- Continuity of flight

5. OXYGEN SYSTEMS - When and how to use.

For flights above 12 000 ft AMSL a serviceable oxygen supply system with a contents gauge visible to the pilot should be carried. Oxygen should be used as soon as the pilot feels the need of it, but in any case above 15 000 ft.

The most desirable system is the diluter-demand type, in which the oxygen is turned on and then an automatic regulator ensures that the pilot breathes air enriched with the appropriate proportion of oxygen. This system is bulky and the regulator needs regular, expensive servicing, but has the advantage of supplying just enough oxygen. It also has a 100% switch which can be used if more oxygen is required..

A simpler system is the constant-flow system where oxygen is delivered to the pilot at a constant rate. *(For components, refer to M Pascoe's notes.)* The oxygen flows into a rubber balloon and a very slight resistance in the outlet from the mask ensures that the first part of the pilot's exhalation flows into the balloon, and his initial inhalation is drawn from it. This system is quite satisfactory except under extreme conditions like prolonged wave flying at very great heights. It is important to use a suitable face mask. The lightweight, emergency variety are likely to freeze up at low

temperatures and are not approved for use below -5°C.

Oxygen cylinders should be handled carefully and should never be emptied completely otherwise moist atmospheric air may enter and cause internal corrosion. They should only be refilled with dry aircraft oxygen. Ordinary medical oxygen contains more moisture and can cause internal icing of the reducing valve.

6. STATICS, PITOTS and TOTAL ENERGY

(Refer to the section on variometers)

7. FINAL GLIDE CALCULATORS

The final glide calculator gives the height needed to accomplish the final glide at a chosen airspeed. It allows for head and tail winds. Calculators on cards are available as well as the more modern electronic types.

8. COMPASSES - Deviation, Inclination and Variation

Errors in Compasses.

a) **Magnetic Deviation.**

The magnet needle of an aircraft compass is affected by the metal parts of the aircraft. This error is called Deviation. It is given in degrees as a sum which must be added or subtracted from the compass reading to give the

magnetic heading.

b) **Inclination (Dip).**

Dip is the angle between the magnetic field of the earth and the horizontal. In the neighbourhood of South Africa it is approximately 60°. Compasses are designed to minimise the effects of dip.

c) **Magnetic Variation (Difference in Magnetic and True North).**

Variation will vary according to the position on the earth of the compass. It also varies slightly from year to year because the Magnetic Pole is moving slowly around the Geographical Pole. The variation is expressed as an angle in degrees between the Magnetic Meridian and the True Meridian. If the variation is to the West, then the value of the variation must be added to a True Heading to get a Magnetic Heading.

d) **Acceleration and Turning Errors.**

It will be found that on Easterly and Westerly headings, any change of speed of the aircraft will cause the compass to show a turn of up to 20°.

The compass can only keep pace

with the glider if turns are gentle - probably less than 10° of bank. Turning errors are maximum on turning on to a heading near North or South and zero on East and West. A rule of thumb for overcoming Turning Error is to

overshoot the required reading by about 20° on a turn on to North and undershoot by the same amount on a turn on to South.

9. HOW TO SWING A COMPASS.

(This should be done as part of the LS1 inspection.)

The reading of a compass installed in a glider is affected by metal components and magnets in other instruments and by electrical currents flowing in adjacent wiring. The effect due to electrical currents can be largely eliminated by using twin flex.

Most compasses are fitted with supplementary magnets to cancel out the influence of stray magnetic fields. To adjust these correctly, it is necessary to determine the errors when the aircraft is pointing in different directions. This process is known as "swinging the compass". This is done using reference points along which the glider can be aligned and the compass reading checked. Note that a non-magnetic screwdriver is required.

If a reference point is not available, the following method can be used. It will give acceptable results provided that the compass is correctly made and it is installed in the aircraft with the proper alignment.

a) Take the glider to a flat area.
b) Install all the usual equipment.
c) Align the glider facing East. If a reference is not available, align it so that the compass reads 90° exactly. Sight along the fuselage to some distant object and remember the position.
d) Turn the glider to face the reverse direction.
e) Read the compass and note the difference from 270°.
f) Adjust the E - W compass correcting magnets to halve this discrepancy.
g) Turn the glider until the compass reads North. Repeat the process described above this time using the magnets for N-S adjustment.
h) If large errors were corrected, repeat the whole procedure.

10. THE MacCREADY SPEED-TO-FLY RING.

Computed from the glider Polar by drawing a tangent to the curve originating from different points on the 'y' axis for lift or sink, and on the 'x' axis for head or tail winds.

The ring can be fitted to the outside of the variometer such that it can be set for various lift readings.

11. TURN and BANK INDICATORS.

Turn precession of the rotating gyro causes a needle deflection as long as the glider is turning about the yaw axis. In the extreme case of a circle with a

90° bank, the turn indicator would remain at zero since there would be no rotation about the yaw axis. This instrument must be used with caution. The bank indicator

consists of a ball in a curved tube, damped by fluid.

12. YAW STRINGS.

The yaw string indicates the direction of the relative wind. Care should be taken with the positioning of the string, so that there will be no interference from the slipstream.

The rule to centre the string:

Follow the string with the stick or pull the string back to centre with opposite rudder.

Ronnie Moore.

Graphics by David Starke

(see Appendix (ii) for suggested reading)

BE

CONSIDERATE

AT ALL TIMES

Airmanship

Airmanship

Airmanship

Airmanship

Airmanship

Airmanship

Airmanship

Airmanship

Airmanship

AIRMANSHIP

Airmanship