DOCUMENT

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DOCUMENT TITLE

FLIGHT INSTRUMENTS

CHAPTER 3 – THE AIRSPEED INDICATOR

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CONTENTS .... PAGE

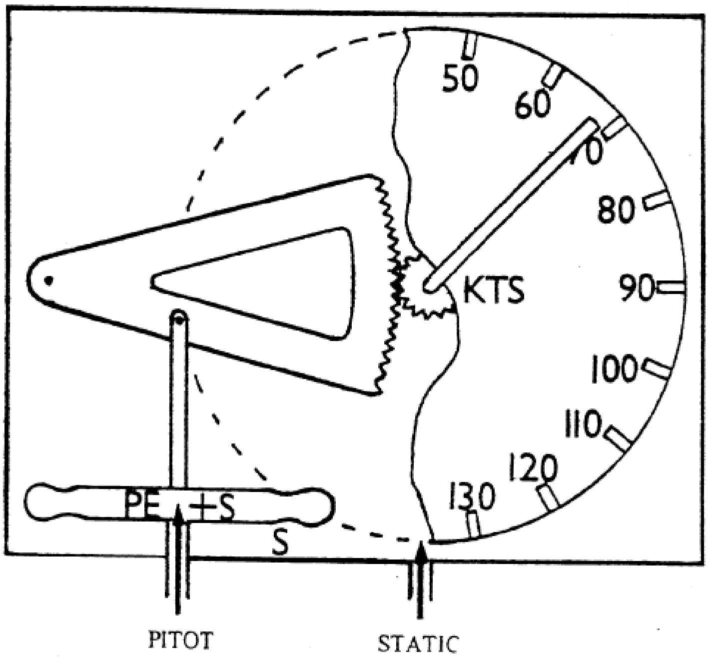
AIRSPEED INDICATOR (ASI)

The airspeed indicator measures dynamic pressure and expresses it as airspeed. The pitot tube senses TOTAL pressure (dynamic and static) and feeds this pressure into a capsule in the ASI. As only dynamic pressure is required, static pressure from the static vent is fed to the outside of the airspeed capsule , so cancelling the static portion of the total pressure. Consequently the resultant size of the capsule is proportional to dynamic pressure only. A mechanical linkage converts this displacement to indicated airspeed.

Note: PITOT = DYNAMIC + STATIC

$\therefore$ DYNAMIC = PITOT - STATIC

Dynamic pressure is shown by the ASI as INDICATED AIRSPEED



Note that in the diagram above, PE refers to PITOT EXCESS which is an alternative term for DYNAMIC PRESSURE.

At low speeds it can be assumed that:-

Dynamic pressure = ½ ρV^2 where ρ is air density and V is True Airspeed (TAS).

CALIBRATION

To evaluate V from dynamic pressure, air density must be known. In practice the ASI has no knowledge of air density and so an assumption has to be made about its value. The calibration of the ASI assumes that the air density corresponds to that of the International Standard Atmosphere at mean sea level. It is immediately obvious that the Indicated Airspeed can only correspond to True Airspeed when the aircraft is flying in the density conditions assumed in calibration. Normally the aircraft is flying in lower density conditions where it must fly faster to achieve a given dynamic pressure. For this reason, TAS is normally greater than IAS.

Ignoring for the moment the effects of other minor sources of error and assuming low speed it can be said that:

$$\text{Dynamic pressure} = \tfrac{1}{2}\,\rho\ \text{ambient}\ V_{TAS}^2$$

$$= \tfrac{1}{2}\,\rho\ \text{ISA msl}\ V_{IAS}^2$$

$$\text{and so } V_{TAS} = V_{IAS} \times \sqrt{\frac{\rho\ ISA\ MSL}{\rho\ Ambient}}$$

The expression $\sqrt{\frac{\rho\ ISA\ MSL}{\rho\ Ambient}}$ is termed "the square root of the inverse of the relative density" and it largely explains the difference between IAS and TAS.

The following figures apply in the Standard Atmosphere.

HEIGHT (ft)	INVERSE OF RELATIVE DENSITY	$\sqrt{\frac{\rho\ \text{ISA MSL}}{\rho\ \text{Ambient}}}$	IAS kts)	TAS (kts)
MSL	1.0	1.0	100	100
5,000	1.16	1.07	100	107
15,000	1.59	1.26	100	126
22,000	2.0	1.414	100	141
30,000	2.67	1.635	100	164

COMPRESSIBILITY

At high speed another significant source of error applies. The air ahead of (and within) the pitot tube becomes compressed and the consequent increase in density, compared to ambient, results in increased pitot pressure and so increased indicated airspeed. Modern instruments are calibrated to formulae that make allowance for compressibility error at mean sea level in ISA conditions, such as:

$$\text{Dynamic pressure} = {}^{1}/_{2}\,\rho V^2 \left(1 + \frac{V^2}{4a^2}\right)$$

Where V = IAS; ρ = ISA MSL density, and a = ISA MSL speed of sound

At altitudes above mean sea level, especially at high speeds, the allowance for compressibility error is insufficient. Allowance must be made for compressibility when CAS> 200 knots or TAS> 300 knots by means of a correction which increases with both speed and altitude. Alternatively TAS can be found from Mach number which is free of compressibility error. Practice in these calculations will be provided in Flight Planning.

OTHER MINOR SOURCES OF ERROR

The ASI, like all pressure instruments, suffers from position and manoeuvre-induced errors. Incorrect sampling of either pitot or static pressures results in errors which are normally not greater than 2 knots. In some conditions, such as low speed with gear and flaps extended, errors can be greater. When the alternative static source is selected, errors can be as much as 10 knots. Instrument errors are caused by manufacturing tolerances. The errors are determined during calibration and any necessary correction is combined in the flight manual with that for position error.

BLOCKAGES AND LEAKS IN THE PITOT -STATIC SYSTEM

BLOCKAGES

If the pitot tube is blocked, by ice for example, the ASI will not react to changes of airspeed in level flight. The capsule will however react to changes in static resulting from changes in altitude. In effect the ASI will act like an altimeter showing increasing airspeed when climbing and decreasing airspeed when descending.

If the static tube is blocked, the ASI will over-read at lower altitudes and under-read at higher altitudes than that at which the blockage occurred.

LEAKS

A leak in the pitot tube will cause the ASI to under-read. The effect of a leak in the static tube depends on whether it occurs inside or outside the pressurized compartments of the aircraft. If within the pressurized areas, the ASI will under-read.

It should be noted that a problem that causes the ASI readings to over-read is potentially dangerous as the aircraft will stall at a higher than normal indicated airspeed.

EXPRESSIONS OF AIRSPEED

IAS (Indicated Airspeed) refers to the reading of the instrument.

CAS (Calibrated or Corrected Airspeed) refers to IAS corrected for instrument & position error.

RAS (Rectified Airspeed) is UK terminology, equivalent to CAS.

EAS (Equivalent Airspeed) is CAS/RAS corrected for compressibility error.

TAS (True Airspeed) is the actual speed of the aircraft relative to the air through which it is flying. It is found from EAS corrected for density error.

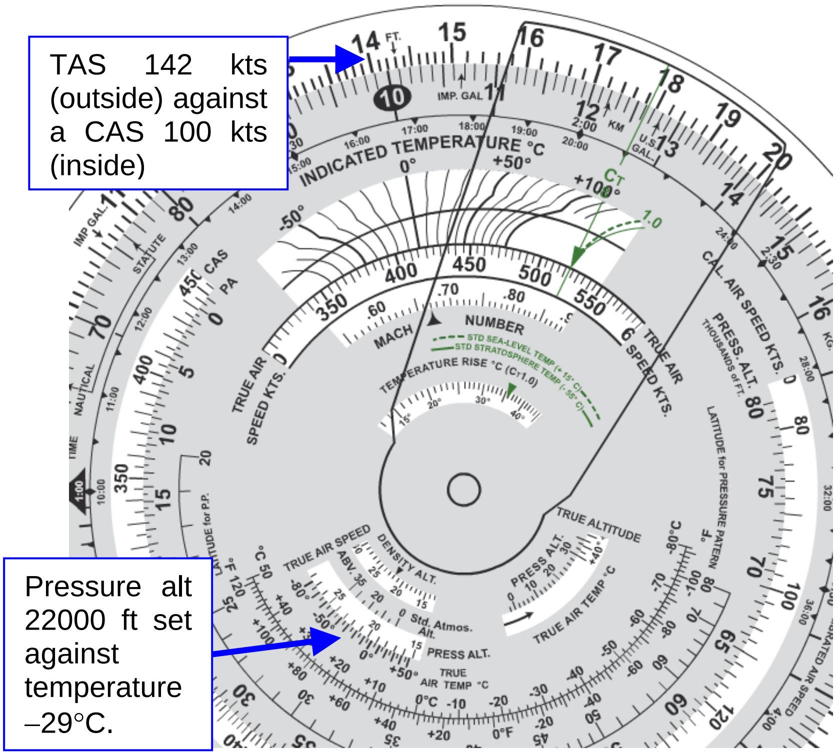
Notes:

- Flight manuals may refer to IAS as the instrument reading and in this case a combined correction for instrument and position errors is provided to obtain CAS or RAS.
- Air Data Computers can effectively eliminate instrument and position errors so that the reading is CAS.
- EAS is the purest expression of the dynamic pressure on which the handling of the aircraft depends. It is an aerodynamic expression of airspeed which would not normally be found in flight manuals.

CONVERSION OF IAS TO TAS

Firstly, IAS must be converted to RAS or CAS by applying a correction for position and instrument errors, normally available as a table in the aircraft's flight manual. Secondly, correction is required for density error. This is achieved on the navigation computer by setting pressure altitude and outside air temperature in the TAS window. TAS can then be read on the outside scale over RAS or CAS on the inside scale.

In the example below, TAS is required for an aircraft maintaining an RAS (or CAS) of 100kt at FL220 with temperature –29°C.



Note that at higher speeds (TAS> 300kt), correction is required for compressibility error. Practice in speed conversion problems is provided in Navigation and Flight Planning classes.

ASI - USE OF COLOURED ARCS AND OTHER MARKERS

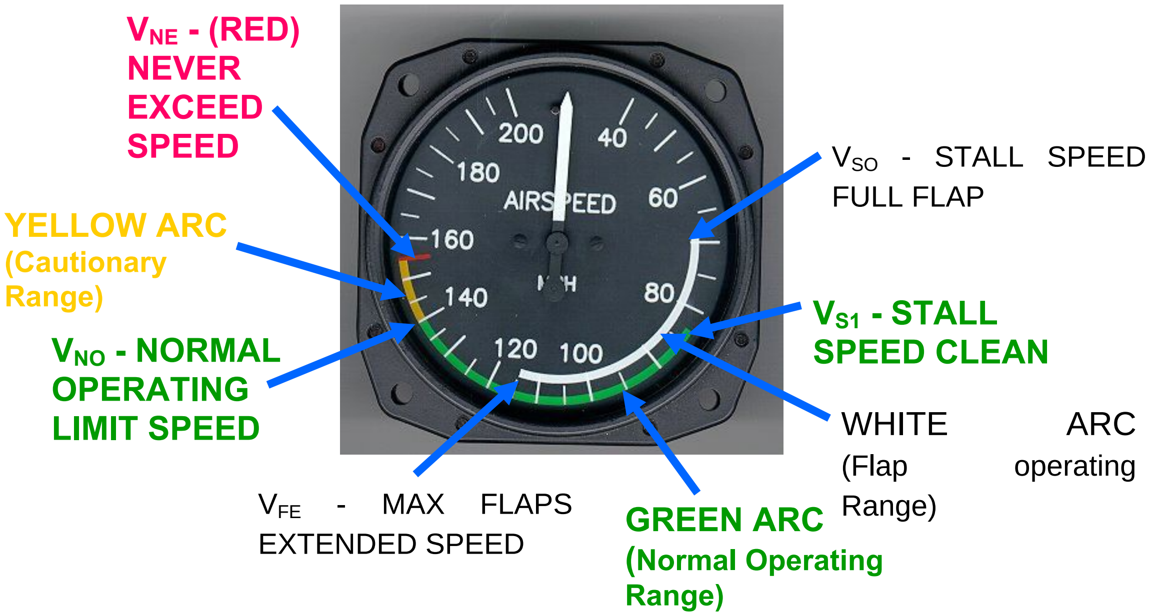
Airspeed indicators may be marked with speed ranges and specific speeds using a conventional colour code:

Green arc indicates the normal- operating speed range, from stall speed to the normal operating limit speed.

Yellow arc indicates the caution range, from the normal- operating limit speed to the never-exceed speed.

White arc indicates the flaps operating range, from the stall speed full flaps to the maximum flaps -extended speed.

Red radial line indicates the never- exceed speed.


V_{NE} - (RED) NEVER EXCEED SPEED
YELLOW ARC (Cautionary Range)
V_{NO} - NORMAL OPERATING LIMIT SPEED
V_{FE} - MAX FLAPS EXTENDED SPEED
GREEN ARC (Normal Operating Range)
WHITE ARC (Flap operating Range)
V_{S1} - STALL SPEED CLEAN
V_{SO} - STALL SPEED FULL FLAP
200
180
160
140
120
100
80
60
40
AIRSPEED
MPH