Federal Aviation Administration

Memorandum

Date: June 19,2006

To: Manager, Small Airplane Directorate, ACE-100

From: Manager, Airplane Certification Office, ASW-150

Prepared by: Lowell Foster, Aerospace Engineer, ACE-111

Subject: Request for Review and Concurrence with an Equivalent Level of Safety (ELOS) ACE-05-32, to 14 CFR, Part 23, §§ 23.1545(a) and 23.1581(d) for Indicated Airspeeds

This memorandum documents concurrence for the subject finding of Equivalent Level of Safety (ELOS). We request your office to review and concur with the proposed ELOS finding to 14 CFR, part 23, §§ 23.1545(a) and 23.1581(d) for indicated airspeed. The proposed ELOS will allow for the use of equivalent airspeed (EAS) to be displayed to the pilot as "indicated" airspeed.

STATEMENT OF ISSUE:

14 CFR, part 23, § 23.1545(a) requires that each airspeed indicator must be marked as specified in this section, with the marks located at the corresponding indicated airspeeds. In addition, 14 CFR, part 23, § 23.1581(d) requires that all Airplane Flight Manual (AFM) operational airspeeds, unless otherwise specified, must be presented as indicated airspeeds. 14 CFR, part 1 defines "indicated airspeed" as the speed of an aircraft as shown on its pitot static airspeed indicator calibrated to reflect standard atmospheric adiabatic compressible flow at sea level uncorrected for airspeed system errors. Eclipse Aviation intends to comply with §§ 23.1545 and 23.1581 by indicating equivalent airspeed. The proposed design provides an "indicated airspeed" to the pilot without the need to compensate for operating speed variations with altitude or compressibility effects. We consider this approach to be in conflict with the strict definition of "indicated airspeed" as defined by 14 CFR, part 1.

BACKGROUND:

The 14 CFR, part 1 definition of indicated airspeed is based on traditional airspeed indicating systems that present speeds to the pilot on a mechanical airspeed indicator that is based on the uncorrected measurement of total and static pressures. Today, however, most new airspeed

indicating systems incorporate air data computers and electronic flight instrument systems that compensate for airspeed indicating errors and display calibrated airspeed. This has been standard practice in transport airplanes for more than a decade. Honeywell's Primus and Epic systems are examples of approved avionic designs that display calibrated airspeed. In addition to calibrated airspeed, current generation avionic architectures have the capability to internally compensate for variations in altitude and compressibility effects. While the current systems can incorporate this compensation into the airspeed directly, they have not done so; instead using the compressibility compensation to continuously adjust the red (max speed) line for conditions. This additional compensation applied to the airspeed directly provides "indicated airspeed" that is based on equivalent airspeed.

The Eclipse 500 is a small jet under 6,000 pounds with a proposed V_{MO}/M_{MO} of 275/.64 and 41,000 feet maximum operating altitude. Eclipse Aviation intends to display equivalent airspeed as "indicated airspeed" on the proposed Eclipse 500 avionic design. Equivalent airspeed is provided by two Harco Air Data Computers (ADCs) and is displayed on the pilot's and copilot's Primary Flight Displays (PFDs). In addition, equivalent airspeed is provided on the standby flight display by a third pitot probe that incorporates an integral air data computer.

To our knowledge, an avionic design that displays equivalent airspeed as "indicated airspeed" has not been previously approved for use in civil aviation; however, this design has been incorporated on various high performance military aircraft. Airspeeds presented to the pilot must be in "indicated airspeed" as required by §§ 23.1545 and 23.1581 unless otherwise noted. Displaying equivalent airspeed conflicts with the definition of "indicated airspeed" as defined by 14 CFR, part 1; however, so does an approved airspeed indicating system that displays calibrated airspeed. A proposed advantage is that equivalent airspeed provides a normalizing function of what the aircraft actually experiences throughout its speed and altitude envelope and is used for all aerodynamic and structural load calculations. As a result, the various operating speed limitations do not need compensation for altitude and compressibility effects. Additionally, computing an equivalent airspeed may allow for a more accurate computation of true airspeed that may be required for speed reporting devices such as Mode S transponder.

FAA POSITION:

General:

Sections 23.1545(a) and 23.1581(d) require that operating speeds be in terms of indicated airspeed. The original intent of this language was to make sure that the speeds in the Airplane Flight Manual matched those on the airspeed indicator. Until this recent rule change, the references to airspeed in part 23 called for calibrated airspeed in subpart B and equivalent airspeed in subpart C. The proposed Eclipse 500 avionics design does not strictly comply with the 14 CFR, part 1 definition of "indicated airspeed;" however, the design complies with the intent of §§ 23.1545(a) and 23.1581(d) in that the various operating speeds are presented in units of what is indicated to the pilot. Additionally, § 23.1545(d) does allow for the display of V_{MO}/M_{MO} to vary with altitude or compressibility effects, or to provide a single red line at the lowest value of V_{MO}/M_{MO} established for any altitude up to the maximum operating altitude. The proposed Eclipse design presents an airspeed to the pilot that compensates for altitude and compressibility effects, negating the need to vary V_{MO}/M_{MO} with altitude and compressibility

effects. The result is that the speeds remain unchanged, simplifying the pilot's responsibility to remember speed limitations.

The effects of presenting equivalent airspeed to the pilot in subparts of 14 CFR, part 23, including other concerns, are discussed below.

Subpart B – Flight:

Sections 23.49 and 23.149 require that stall and minimum control speeds be determined in calibrated airspeed. This is a prescriptive requirement to determine those speeds in terms of calibrated airspeed. The proposed Eclipse design is compliant because all flight test speeds contained in the flight test reports will include calibrated airspeed.

Subpart C – Structure:

Section 23.335 states that the design speeds are equivalent airspeeds. The various operating speeds are determined relative to design speeds, and the proposed Eclipse design is compliant by presenting the various operating speeds to the pilot in equivalent airspeed.

Subpart D – Design and Construction:

Section 23.629 states the flutter requirements in terms of equivalent airspeeds. This is a prescriptive requirement. The approved operating speed envelope is based on flutter compliance, and the proposed Eclipse design is compliant by presenting the appropriate operating speeds in equivalent airspeed.

Subpart F – Equipment:

Section 23.1323 states that each airspeed system must be calibrated in flight to determine the system error. The proposed Eclipse design is compliant in that system errors for the primary and standby instruments will be calibrated in flight.

Other Issues and Concerns:

With respect to operating in the National Airspace System, the proposed Eclipse 500 maximum operating limit speed (V_{MO}/M_{MO}) of 275/.64 results in a maximum equivalent airspeed correction of approximately minus 8 knots airspeed. This may result in a maximum 8 knots difference in true airspeed between an Eclipse 500 and another aircraft flying in the same atmospheric conditions and indicated airspeed. In addition, when considering the 250 knot speed restriction for altitudes less than 10,000 feet indicated, the maximum equivalent airspeed correction at 10,000 feet altitude and 250 knots calibrated is less than 2 knots.

The ability of an avionic design to calculate an equivalent airspeed will allow for a more accurate computation of true airspeed for use with speed reporting devices such as Mode S transponder.

APPLICANT POSITION:

The Eclipse 500 has more than adequate computing power to provide the pilot with equivalent airspeed as "indicated airspeed." This design does not require airspeed compensation with altitude and airspeed. This fully complies with the original intent of the 14 CFR, part 23 paragraphs, but conflicts in detail with the requirements of 14 CFR, part 23, § 23.1545(a) and 23.1581(d), which require the airspeed information to be supplied as "indicated airspeeds." The logic of these requirements is to provide information on the cockpit instruments and the AFM in the same units.

Eclipse proposes to provide the airspeed indication to the pilot that has compensation for instrument error, position error and compressibility effects. All paragraphs in 14 CFR, part 23 would be complied with, but the "indicated airspeed" definition of 14 CFR, part 1 would be in conflict with presenting equivalent airspeed to the pilot. A complete applicant position is provided in the attached Eclipse Aviation Position Paper dated March 29, 2006 (see attached).

CONCLUSION:

Displaying equivalent airspeed falls into a grey area for compliance because of the 14 CFR, part 1 definition; however, we find that there are no safety concerns with Eclipse's approach. Precedence by the transport directorate to allow display of calibrated airspeed without going through the equivalent safety process was considered. In their case, displaying calibrated airspeed does not meet the literal compliance of part 1 either. We believe that an equivalent safety finding is the best approach to address the strict compliance with the 14 CFR, part 1 definition issue and to document this decision that allows equivalent airspeed to be displayed to the pilot on the airspeed indicator.

The impact from indicating equivalent airspeed on air traffic in the National Airspace System is negligible. Discussions with the FAA's Enroute Operations Standards Office personnel yielded several considerations:

a. ATC has seen airspeed differences in airplanes for decades, this isn't new nor does it create an un-manageable conflict.
b. Spacing airplanes for arrivals and departures is the most typical place where ATC will call out speeds. Typically they will adjust aircraft speeds using increments of 10 knots faster or slower.
c. Approach and departure airspeed and altitudes are not typically fast enough or high enough for significant compressibility effects. This is true of Eclipse, or any fast part 23 airplane, where the speed difference between calibrated and equivalent is about 4 knots at 18,000 feet and 250 knots.
d. ATC uses ground speed to estimate airspeeds.

e. ATC has been controlling airplanes flying with difference performance and indicating systems for years without a problem. They handle high altitude recips flying indicated, jets flying Mach, and select military aircraft flying equivalent airspeed without difficulty.

Furthermore, there was considerable concern that this one equivalent safety finding would lead to other, faster airplanes displaying equivalent airspeed. One reason we are granting this equivalency is that the Eclipse airplane is relatively slow and the airspeed differences between indicated and equivalent are less than 10 knots below the altitude for transition to flying Mach numbers. If other projects want to indicate equivalent airspeed, they will have to be evaluated on a case by case basis.

Concurred by:

Michele M. Owsley	*6-6-06*
Manager, Airplane Certification Office, ASW-150	Date
William J. Timberlake	*6-9-06*
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James E. Jackson	*6-19-06*
for Manager, Small Airplane Directorate, ACE-100	Date

Appendix A *(applicant's position)*

Position Paper on the cockpit presentation of EAS versus IAS speed

(Note: Any direct quote from a FAR document is in italics, blue text)

The definitions of Indicated Airspeed (IAS) and Calibrated Airspeed (CAS) evolved over the 100+ years of powered flight because of the limited capabilities of the mechanical airspeed indication system to provide more accurate information to the pilot. What the aircraft responds to both aerodynamically as well as structurally is Equivalent Airspeed (EAS), but it is only with the availability of fast computers that this information can now be displayed directly to the pilot.

Eclipse Aviation will demonstrate in the following paragraphs that presenting speed information to the pilot as EAS instead of CAS or IAS fulfils the intent of the regulations and does not provide any problem to the National Airspace System Air Traffic Control.

Definitions (from CFR 14 Part 1)

Indicated airspeed means the speed of an aircraft as shown on its pitot static airspeed indicator calibrated to reflect standard atmosphere adiabatic compressible flow at sea level uncorrected for airspeed system errors.

Calibrated airspeed means the indicated airspeed of an aircraft, corrected for position and instrument error. Calibrated airspeed is equal to true airspeed in standard atmosphere at sea level

Equivalent airspeed means the calibrated airspeed of an aircraft corrected for adiabatic compressible flow for the particular altitude. Equivalent airspeed is equal to calibrated airspeed in standard atmosphere at sea level.

True airspeed means the airspeed of an aircraft relative to undisturbed air. True airspeed is equal to equivalent airspeed multiplied by $(\rho 0/\rho)^{1/2}$.

Mach number means the ratio of true airspeed to the speed of sound.

(see also formulae in Attachment B)

Equivalent Airspeed provides the normalizing function of what the aircraft actually experiences throughout its speed and altitude envelope and is used as the basis for all aerodynamic and structural loads calculations.

What the pilot really needs to know are:

- How close he is to the minimum and maximum aircraft limits – this is provided best with data in EAS, which does not vary with altitude
- How fast he is traveling compared to other aircraft and over the ground (to which he has to add or subtract the wind component). This must be provided as TAS.

Examples of airspeed computations

Stall speed:

EAS – 90 kts at all altitudes
CAS – 90 kts at sea level, 89 kts at 40,000 ft
IAS – 88 kts at sl, 87 kts at 40k (assuming -2 kts PE)

V_{MO} speed:

EAS – 275 kts at all altitudes
CAS – 275 kts at sl, 279 kts at 20,000 ft
IAS – 281 kts at sl, 275kts at 20, 000 ft (assuming -4 kts PE)

Using EAS allows the pilot to remember a single limiting speed which does not change with altitude

Certification concerns

Attachment A provides extracts from CFR 14 Part 23 covering references to indicated and calibrated airspeeds (there are some additional references in SFAR and Commuter category which have not been included)

In general, the references to indicated and calibrated airspeeds are confusing:

Subpart C: The structures paragraphs §23.335 and 629 use EAS exclusively.

Subpart B: Stall speed and V_{MC} must be determined in CAS (but provided in the AFM in IAS, see below). Throughout Part B, speeds are either referred to as multiples of the stall speeds or as one of the structural limit speeds (in EAS) defined in Part C.

Subpart F: The only requirements in §23.1323 Airspeed Indicating System regarding units, is that *"Each airspeed indicating instrument must be calibrated to indicate true airspeed (at sea level with a standard atmosphere) with a minimum practicable instrument calibration error ... "*

Subpart G: §23.1545 requires that the markings placed on the airspeed indicator are in the correct units: *"Each airspeed indicator must be marked … with the marks located at the corresponding indicated airspeeds."*

§23.1545d accepts that using indicated airspeed results in large inaccuracies at higher speeds and altitudes: *"…for those aircraft there must either be a maximum allowable airspeed indication showing the variation of V_{MO}/M_{MO} with altitude or compressibility limitations (as appropriate) ….."*

§23.1581d requires that the AFM information is the same as that presented to the pilot on his airspeed indicator: *"All AFM operational airspeeds, unless otherwise specified, must be presented as indicated airspeeds*". Interesting here is the usage of the phrase "…**unless otherwise specified** ….", which would indicate that something different than indicated airspeeds would be acceptable.

To summarize the above: The FAA requirements are to provide the pilot with airspeed limits in the AFM which he can associate with the speeds being presented to him on his airspeed indicator. The only requirements to convert these speeds into CAS are for flight test, so that the correct factors can be applied when computing 1.2 V_S, 1.4 V_S, etc.

The regulations accept the limitation of this system in that compensating charts or conservative values must be used to account for the changes in these values over the altitude and speed range of the aircraft.

Eclipse compliance proposal for the above paragraphs:

- Eclipse will quote the stall speed and V_{MC} in CAS as well as other units in our certification documentation, thereby complying with §23.49 and §23.149
- §23.1323 is fulfilled by providing calibration information
- §23.1545 requires Eclipse to provide marks at the corresponding "indicated airspeed". Since IAS is itself a corrected value, we can provide <u>all</u> of the corrections in our "indication" and declare that as indicated (equivalent) airspeed.
- §23.1545d: Using EAS means that no "variation with altitude or compressibility" needs to be provided.
- §23.1581 requires AFM information to be presented as IAS "unless otherwise specified…". Eclipse proposes to specify it "otherwise" as EAS

- §23.1587 requires only the relationship between IAS and CAS to be determined. Eclipse will provide that information and declare that the airspeeds that we "indicate" require zero correction to achieve EAS and that CAS is not relevant for this aircraft

Air Traffic Control concerns

Eclipse Aviation has reviewed the regulations pertaining to Air Traffic Control, in particular Order 7110.65P. The Order is not very clear on its use of units for airspeed. In most cases no units for airspeed are quoted, in some cases IAS is used and in some cases CAS is used. For instance, Chapter 5 "Radar", Section 7 "Speed adjustments":

> ***e.*** *Express speed adjustments in terms of knots based on indicated airspeed* ***(IAS)*** *in 10-knot increments. At or above FL 240, speeds may be expressed in terms of Mach numbers in 0.01 increments for turbojet aircraft with Mach meters (i.e., Mach 0.69, 0.70, 0.71, etc.).*

and later in the same chapter:

> ***1.*** *On a standard day the Mach numbers equivalent to 250 knots* ***CAS*** *(subject to minor variations) are:*
> *FL 240-0.6*
> *FL 250-0.61*

However, most of the procedures determine separation between aircraft by either time or distance, not speed.

Also, all of the information provided for a flight plan (see Order 7110.65 Chapt 2, Section 2-2-2 and FAA form 7233-1 (8-82) requires for the airspeed information to be provided as **True Airspeed**. Furthermore, the data that is provided by a Mode-S transponder is also **True Airspeed** and this is the primary information that the Air Traffic Controller now uses for aircraft separation.

Based on the above and the fact that the maximum speed permitted at 10,000 ft is 250 kts, where the compressibility correction (difference between CAS and TAS) is less than 2 kts, Eclipse believes that the usage of EAS instead of IAS or CAS has **no impact** on the Air Traffic Control System.

Training

Eclipse Aviation believes that that there will be no impact on training due to this change. It is still important to inform pilots how airspeed in measured, but it will not negatively affect the pilots by eliminating an unnecessary mental computation task. Providing EAS instead of uncorrected Indicated Airspeed is both logical and simple.

Conclusion

Eclipse Aviation believes that presenting equivalent airspeed to the pilot, in addition to fulfilling the intent of the airworthiness standards, has no effect on pilot training nor on operations within the National Airspace System.

---------- End ----------

Attachment A - extracts from FAR part 23 mentioning IAS or CAS

§ 23.49 Stalling period.

(a) V_{SO} and V_{S1} are the stalling speeds or the minimum steady flight speeds, in knots (CAS), at which the airplane is controllable with—

(1) For reciprocating engine-powered airplanes, the engine(s) idling, the throttle(s) closed or at not more than

§ 23.149 Minimum control speed.

(a) V_{MC} is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative, and thereafter maintain straight flight at the same speed with an angle of bank of not more than 5 degrees. The method used to simulate critical engine failure must represent the most critical mode of powerplant failure expected in service with respect to controllability.

§ 23.1323 Airspeed indicating system.

(a) Each airspeed indicating instrucment must be calibrated to indicate true airspeed (at sea level with a standard atmosphere) with a minimum practicable instrument calibration error when the corresponding pitot and static pressures are applied.

(b) Each airspeed system must be calibrated in flight to determine the system error. The system error, including position error, but excluding the airspeed indicator instrument calibration error, may not exceed three percent of the calibrated airspeed or five knots, whichever is greater, throughout the following speed ranges:

(1) 1.3 V_{S1} to V_{MO}/M_{MO} or V_{NE}, whichever is appropriate with flaps re-

§ 23.1545 Airspeed indicator.

(a) Each airspeed indicator must be marked as specified in paragraph (b) of this section, with the marks located at the corresponding indicated airspeeds.

(b) The following markings must be made:

(1) For the never-exceed speed V_{NE}, a radial red line.

(2) For the caution range, a yellow arc extending from the red line speci-

(d) Paragraphs (b)(1) through (b)(3) and paragraph (c) of this section do not apply to aircraft for which a maximum operating speed V_{MO}/M_{MO} is established under §23.1505(c). For those aircraft there must either be a maximum allowable airspeed indication showing the variation of V_{MO}/M_{MO} with altitude or compressibility limitations (as appropriate), or a radial red line marking for V_{MO}/M_{MO} must be made at lowest value of V_{MO}/M_{MO} established for any altitude up to the maximum operating altitude for the airplane.

AIRPLANE FLIGHT MANUAL AND APPROVED MANUAL MATERIAL

§23.1581 General.

(a) *Furnishing information.* An Airplane Flight Manual must be furnished with each airplane, and it must contain the following:

(1) Information required by §§23.1583

.....

(d) All Airplane Flight Manual operational airspeeds, unless otherwise specified, must be presented as indicated airspeeds.

(e) Provision must be made for stowing the Airplane Flight Manual in a suitable fixed container which is readily accessible to the pilot.

(f) *Revisions and amendments.* Each

§23.1587 Performance information.

Unless otherwise prescribed, performance information must be provided over the altitude and temperature ranges required by §23.45(b).

(a) For all airplanes, the following information must be furnished

.....

(ii) The landing distance determined under §23.75 for each airport altitude and standard temperature.

(10) The relationship between IAS and CAS determined in accordance with §23.1323 (b) and (c).

Attachment B – Equations and definitions of Airspeed

From Wikipedia, the free encyclopedia

Airspeed refers to the speed of an aircraft relative to the air. There are several different measures of airspeed viz. indicated airspeed, calibrated airspeed, equivalent airspeed and true airspeed. The different measures of airspeed and their derivation from the aircraft instrumentation are discussed below.

Indicated airspeed

Indicated airspeed (IAS) is the airspeed indicator reading (ASIR) corrected only for instrument error.

Outside of the former Soviet bloc, most airspeed indicators show the speed in knots i.e. nautical miles per hour. Some light aircraft have airspeed indicators showing speed in miles per hour.

An airspeed indicator is a differential pressure gauge with the pressure reading expressed in units of speed, rather than pressure. The airspeed is derived from the difference between the total pressure i.e. static plus dynamic air pressure and the static air pressure. The total pressure is usually detected by a pitot tube which is mounted facing forward; the static pressure is usually detected at static ports on one or both sides of the aircraft. Sometimes both pressure sources are combined in a single probe, a pitot-static tube. The static pressure measurement is subject to error due to inability to place the static ports at positions where the pressure is true static pressure. The correction for this error is the position error correction (PEC).

The airspeed indicator shows the airspeed calculated as follows:

$$V_i = \sqrt{\frac{p_t - p}{\frac{1}{2}\rho_0}}$$

Where

V_i is the indicated airspeed,
p_t is the total air pressure sensed by the pitot tube,
p is the static air pressure sensed at the static source,
ρ_0 is 1.225 kg/m³, the air density at sea level, ISA conditions.

This expression is based on the form of Bernoulli's equation applicable to a perfect, incompressible, gas. The air density used is that at SL, ISA i.e. the conditions under which airspeed indicators are calibrated.

(Modern airspeed indicators are calibrated for compressible flow at sea level ISA, see link to calibrated airspeed)

Calibrated airspeed

Calibrated airspeed (CAS) is indicated airspeed corrected for position error.

Equivalent airspeed

Equivalent airspeed (EAS) is calibrated airspeed corrected for error due to air compressibility which arises at high altitudes and mach numbers. Under standard sea level conditions EAS is the same as CAS.

Let q represent the dynamic pressure $\frac{1}{2}\rho V^2 = \frac{1}{2}\rho_0 V_e^2$.

Then the relationship between the pressure difference $p_t - p$ sensed by a pitot-static system and the dynamic pressure is given by:

$$\frac{p_t - p}{q} = \frac{V_i^2}{V_e^2} = 1 + \frac{1}{4}M^2 + \frac{(2-\gamma)}{24}M^4 + \frac{(2-\gamma)(3-2\gamma)}{192}M^6 + \ldots$$

Where

M is the Mach number,
V is the true airspeed,
V_e is the equivalent airspeed,
γ is the ratio of the specific heats of air and
ρ is the air density.

The ratio of the specific heats, γ, is 1.4 in air. Substituting this value gives:

$$\frac{p_t - p}{q} = \frac{V_i^2}{V_e^2} = 1 + \frac{1}{4}M^2 + \frac{1}{40}M^4 + \frac{1}{1600}M^6 + \ldots$$

(This section needs editing due to confusion between V (TAS) and Vi (CAS) and ambiguity regarding ASI calibration - incompressible flow equation above or compressible flow equation under calibrated airspeed? If the ASI is calibrated to the CAS calibration equation which (for subsonic speeds) eliminates compressibility error at standard sea level then the compressibility correction above is not valid.)

This approximation is valid up to about Mach 2.3.

Source: Aerodynamics of a Compressible Fluid. Liepmann and Puckett 1947. Publishers John Wiley & Sons Inc.

The difference between calibrated airspeed and equivalent airspeed is negligible at low Mach numbers rising to 3% at Mach 0.5 and 13% at Mach 1 depending on altitude.

The significance of equivalent airspeed is that at Mach numbers below the onset of wave drag, all of the aerodynamic forces and moments on an aircraft scale with the square of the equivalent airspeed. The equivalent airspeed is closely related to the Indicated airspeed speed shown by the airspeed indicator. Thus, the handling and 'feel' of an aircraft, and the aerodynamic loads upon it, at a given equivalent airspeed, are very nearly constant and equal to those at SL, ISA irrespective of the actual flight conditions.

True airspeed

True airspeed (TAS) is the true speed of the aircraft relative to the air. It differs from the equivalent airspeed because the airspeed indicator is calibrated at SL,ISA conditions, where the air density is 1.225 kg/m³ , whereas the air density in flight normally differs from this value.

The relationship between true airspeed and equivalent airspeed (V_e)is given by:

$$\frac{1}{2}\rho V^2 = q = \frac{1}{2}\rho_0 V_e^2$$

Thus

$$\frac{V}{V_e} = \sqrt{\frac{\rho_0}{\rho}}$$

Where

ρ is the air density at the flight condition.

The air density may be calculated from:

$$\frac{\rho}{\rho_0} = \frac{p\,T_0}{p_0\,T}$$

Where

p is the air pressure at the flight condition,

p_0 is the air pressure at sea level = 1013.2 hPa,

T is the air temperature at the flight condition,

T_0 is the air temperature at sea level, ISA = 288.15 K.

Source: Aerodynamics of a Compressible Fluid. Liepmann and Puckett 1947. Publishers John Wiley & Sons Inc.