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# Notes on Definitions of and Nomenclature for "Air Speeds"

By

the Staff of the Aeroplane and Armament Experimental Establishment

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1951

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C.P. No.49

# Notes on Definitions of and Nomenclature for Air Speeds*

- By -
The Staff of the Aeroplane and Armament Experimental Establishment,
Boscombe Down.

Communicated by the Principal Director of Scientific Research (Air),

Ministry of Supply

22nd November, 1950

## 1. Introduction

The true air speeds of aircraft are commonly derived from the readings of "air speed indicators" which are in fact sensitive pressure gauges. In this derivation a number of parameters occur which are defined slightly differently by different users. In some cases the same name is given to two differently defined quantities.

The definitions and notations adopted by five bodies (B.S. Glossary, R.Ae.S., Air Ministry, the U.S. and I.C.A.O.) are discussed below and comment made on the possibilities of confusion between them.

## 2. The Parameters Used

The various parameters used by the various authorities in connection with air speed measurement are listed below.

(i) The actual reading of a particular instrument in a particular aircraft.

(ii) The instrument reading (i) corrected for instrument error.

(iii) The instrument reading (i) corrected for instrument error and for errors in registering free stream pitot and static pressures.

(iv) The instrument reading (i) corrected for instrument error and for errors in registering the free stream pitot and static pressures which would occur at ground level at the same value of the instrument reading.

(v) The true speed of the aircraft relative to undisturbed air, multiplied by the square root of the relative air density.

(vi) The true air speed of the aircraft relative to the undisturbed air.

The relations between these parameters and their relation to the pitot and static pressures are given in Appendix I together with the significance of various correction processes employed.

3./

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*This paper is appendix to A.R.C. 13,570, received 22nd November, 1950.

3. The Terms Used for these Parameters by the Various Authorities

The terms used for these parameters by various authorities are tabulated below:-

| Parameter (section 2) | British Standard Glossary | R.Ae.S. Data Sheets | Air. Min. (i.e. navigation) | American | I.C.A.O. |
|---|---|---|---|---|---|
| Item (i) | Airspeed indicator reading (A.S.I.R.) | Not used | Indicated air speed (I.A.S.) | Indicated air speed (I.A.S.) | Not used |
| Item (ii) | Indicated air speed (A.S.I.) | Indicated air speed | Not used | Not used | Indicated air speed (I.A.S.) |
| Item (iii) | Not used | Not used | Not used at present | Calibrated air speed (C.A.S.) | Not used |
| Item (iv) | Not used | Not used | Rectified air speed (R.A.S.) | Not used | Not used |
| Item (v) | Equivalent air speed (E.A.S.) | Equivalent air speed (E.A.S.) | Not used | Equivalent air speed (E.A.S.) | Equivalent air speed (E.A.S.) also Calibrated air speed (C.A.S.) |
| Item (vi) | True air speed (T.A.S.) | True air speed (T.A.S.) | True air speed (T.A.S.) | True air speed (T.A.S.) | True air speed (T.A.S.) |

The following comments may be made:-

(a) The major inconsistency appears in the I.C.A.O. definition of C.A.S.; this is in fact identical with E.A.S. and as such is either redundant or incorrectly defined. There is a grave possibility of confusion with the American C.A.S.

(b) Indicated airspeed is not consistently used, there being a roughly equal division between the instrument reading corrected and uncorrected for instrument error.

Point (a) has been raised with the A.R.B. Inconsistency in the definition of indicated airspeed is inconvenient but the quantitative effects are not large.

Fuller details of the definitions, nomenclature and notation used by the various authorities is given in Appendix II.

4./

4. Notation Used for these Parameters by the Various Authorities

The notation used for the parameters is as follows:-

| Parameter (see section 2) | British Standard Glossary | R.Ae.S. Data Sheets | Air Min. (i.e. navigation) | American | I.C.A.O. | A. & A.E.E. (see Report No.Res/244) |
|---|---|---|---|---|---|---|
| Item (i) | | | | $V_i$ | | $V_R'$ |
| Item (ii) | $V_i$ | $V_r$ | | | | $V_R$ |
| Item (iii) | | | | $V_c$ | | $V_r$ |
| Item (iv) | | | | | | |
| Item (v) | | $V_i$ | | $V_e$ | | $V_i$ |
| Item (vi) | V | V | | V | | V |

With regard to notation, the relevant points may be summarised as follows:-

(a) $V_c$ is used in the U.S. for their "calibrated air speed" (Item (iii)).

(b) $V_C$ is used by I.C.A.O. for their "design equivalent cruising speed".

(c) $V_e$ is used in the U.S. for their equivalent air speed (Item (v)).

(d) $V_i$ is used in the U.S. for instrument reading (Item (i)), by the B.S. Glossary for instrument reading corrected for instrument error (Item (ii)), and in general British technical practice, including the R.Ae.S. Data Sheets for "equivalent air speed" (Item (v)).

(e) $V_r$ is used by the R.Ae.S. for the instrument reading corrected for instrument error (Item (ii)).

5./

5. Suggested Scheme of Definitions and Notation

The following scheme of definition and notation is suggested.

| Parameter (see section 2) | Term | Abbrev-iation | Symbol | Definition |
|---|---|---|---|---|
| Item (i) | Air speed indicator reading | A.S.I.R. | - | The reading of an individual instrument. |
| Item (ii) | Indicated air speed | I.A.S. | $V_R$ | The instrument reading corrected for instrument error. |
| Item (iii) | Rectified air speed | R.A.S. | $V_r$ | The instrument reading corrected for instrument error and pressure error. |
| *Item (iv) | ← Will not be required in future → | | | |
| Item (v) | Equivalent air speed | E.A.S. | $V_e$ | The true air speed multiplied by the square root of the relative air density; also equal to the indicated air speed $V_R$ corrected for pressure error and with the scale-altitude term added.+ |
| Item (vi) | True air speed | T.A.S. | V | The speed of the aircraft relative to the air. |

References


| No. | Author | Title, etc. |
|---|---|---|
| 1 | Weaver | The Calibration of Air Speed and Altimeter Systems. AAEE/Res/244. A.R.C. 12,564 |
| 2 | - | D.T.D. Instruction to Experimental Establishments in Relation to Flying Trials. Errors in and Corrections to Indicated Air Speed. |


APPENDIX I/

*It is understood that it is intended to use Item (iii) rather than Item (iv) in future for navigational purposes, and Item (iv) will not therefore be of any practical significance.

+See A. & A.E.E. Res/244 for definitions.

## APPENDIX I

### The Relationship Between the Parameters and the Significance of the Various Correction Processes

1. Basic Relations

The notation used in this Appendix is that of Ref.1 (summarised in column 6 of the Table of section 4 of this note).

The relationship between true airspeed V and the free stream pitot and static pressures $P_p$ , $P_s$ is given by

$$P_p = P_s \left(1 + \frac{\gamma - 1}{2} \frac{V^2}{a^2}\right)^{\frac{\gamma}{\gamma - 1}} \qquad \ldots (1)$$

where a = local speed of sound

or in terms of equivalent air speed $V_i$ and expanding the bracketed expression:-

$$P_p - P_s = \tfrac{1}{2}\rho_o V_i^2 \left(1 + \frac{1}{4}\frac{V_i^2}{p a_o^2} + \frac{1}{40}\frac{V_i^4}{p^2 a_o^4} + \ldots\right) \qquad \ldots (2)$$

where $p = P_s/P_{s_o}$ and suffix o refers to standard sea level conditions.

In American practice airspeed indicators are scaled in accordance with equation (2) for standard pressure altitude zero, that is taking $p = 1.0$*

$$P_P - P_S = \tfrac{1}{2}\rho_o V_R^2 \left(1 + \frac{1}{4}\frac{V_R^2}{a_o^2} + \frac{1}{40}\frac{V_R^2}{a_o^4} \ldots\right) \qquad \ldots (3a)$$

where $P_P$ and $P_S$ are the pressures applied to the instrument.

In British practice indicators are at present scaled in accordance with an approximate form of equation (2) also taking $p = 1.0$ giving

$$P_P - P_S = \tfrac{1}{2}\rho_o V_R^2 \left(1 + \frac{1}{4}\frac{V_R^2}{a_o^2}\right). \qquad \ldots (3b)$$

2. Significance of the Corrections

The following corrections are similar in principle, though arithmetically slightly different, for American and British scaled instruments. The items referred to are those of section 2 of this note.

Item (i)/

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*This scaling is thus only correct for $V_i$ (E.A.S.) at standard pressure altitude zero. It is correct for V (T.A.S.) only at pressure altitude zero and standard temperature.

Item (i) to item (ii)

This correction accounts for any failure in practice to produce exactly the intended scaling according to equation 3(a) or 3(b) as appropriate.

Item (ii) to item (iii)

This correction accounts for any failure to detect "free stream" pitot and static pressures. It is normally called "installation error correction" or "pressure defect correction" in America; it is sometimes called "position error correction" in this country, but this phrase is given a different meaning in Ref.2. It is proposed in Ref.1 that it shall be called "pressure error correction" in this country.

Item (iii) to item (v)

This corrects for the difference between equations 3(a) or 3(b) (in their free stream version) as appropriate, and equation 2. At zero pressure altitude the correction is zero with American instruments and small[x] for British instruments except at high speeds. It increases with altitude and becomes -30 m.p.h. at 30,000 ft and a Mach number of 0.95. It is proposed in Ref.1 that it shall be called the "scale-altitude correction" because it results from the association of the scaling with a single value of $p$ (pressure altitude).

Item (ii) to Item (iv)

This correction has sometimes been used instead of the above. It accounts approximately for any failure to detect "free stream" pitot and static pressures, by applying the correction appropriate to the same $V_R$ at ground level. It is this correction which is called the "position error condition" in Ref.2.

Item (iv) to item (v)

This corrects for residual errors arising from any change with altitude, at constant $V_R$, of the error due to failure to detect free stream pitot and static pressures, and also for the difference between equations 3(a) or 3(b) and equation 2.

APPENDIX II/

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[x]At 400 m.p.h. correction is $\frac{1}{2}$ m.p.h. and at 650 correction is -3 m.p.h.

## APPENDIX II

### Definitions and Notations in General Use

The following is a list of the definitions and notations in use by five authorities.

British Standard Glossary of Aeronautical Terms

Air speed (True airspeed). The speed of the centre of gravity of an aircraft relative to the air. More generally, the speed of air past any fixed or moving object. (Abbrev. T.A.S.): Symbol V.

Equivalent airspeed. The product of the airspeed and the square root of the relative density. (Abbrev. E.A.S.)

Indicated airspeed. The reading of an airspeed indicator corrected for calibration errors only. (Abbrev. A.S.I.). The uncorrected airspeed indicator reading is denoted by A.S.I.R. Symbol $V_i$.

Royal Aeronautical Society Data Sheets

True airspeed. Not defined; symbol V

Equivalent airspeed. $V\sqrt{\sigma}$ : symbol $V_i$

Indicated airspeed. The instrument reading corrected for instrument error: symbol $V_r$.

Air Ministry (AMO A631/42)

Indicated airspeed (I.A.S.) Air speed indicator reading.

Rectified airspeed (R.A.S.) Indicated airspeed corrected for instrument and position errors.

True airspeed (T.A.S.) R.A.S. corrected for height, i.e., for temperature and pressure.

American (N.A.C.A. TN.1120 - TR.837)

True airspeed. Not defined: symbol V

Indicated airspeed. The reading of a differential pressure airspeed indicator, calibrated in accordance with the accepted standard adiabatic formula to indicate true airspeed for standard sea level conditions only, uncorrected for instrument and installation errors: symbol $V_i$.

Calibrated airspeed. The airspeed related to differential pressure by the accepted standard adiabatic formula used in the calibration of differential pressure airspeed indicators and equal to true airspeed for standard sea level conditions: symbol $V_C$.

Equivalent airspeed. $V\sigma^{\frac{1}{2}}$: symbol $V_e$

I.C.A.O. (Dec.3031)

True airspeed. The true airspeed of the aeroplane relative to undisturbed air. (Abbrev. T.A.S.).

Equivalent airspeed. T.A.S. $(\rho/\rho_o)^{\frac{1}{2}}$ : (Abbrev. E.A.S.).

Indicated airspeed. The reading of the pitot static airspeed indicator as installed in the aeroplane, without correction for airspeed indicator system errors : (Abbrev. I.A.S.).

C.P. No. 49
(13,570)
A.R.C. Technical Report

PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

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1951

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PRINTED IN GREAT BRITAIN

86998/K3/3 S O Code No 23-9006-49