DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

# From CAS to EAS – Calculating and Plotting the Compressibility Correction Chart

Task for a *Bachelor Thesis*

## Background

Various speed definitions exist in aviation: indicated airspeed (IAS, $V_I$), calibrated airspeed (CAS, $V_C$), equivalent airspeed (EAS, $V_E$), true airspeed (TAS, $V$), and ground speed (GS, $V_G$). Equations exist to get from one speed to the other. In the direction as given above it is from the "wrong speed to the true speed" in the opposite direction the conversion is from the "true speed to the wrong speed". Relatively cumbersome is the conversion between calibrated airspeed (CAS) and equivalent airspeed (EAS), because this involves the calculation of incompressible flow, and equations are quite long. If calculations on the computer are required, conversions with equations are necessary. However, if quick calculations with a pocket calculator are done, it is good and fast to read the difference $\Delta V_C = V_C - V_E$ as a function of CAS and altitude or CAS and Mach number or Mach number and altitude from a graph. As defined, $\Delta V_C$ is always positive and $V_E = V_C - \Delta V_C$ is always smaller than $V_C$. For CAS up to 100 kt the difference can be neglected for most practical cases. The difference can also be neglected for CAS up to 250 kt, if the altitude is below 10000 ft. In contrast, for Mach 1 and 30000 ft, EAS is almost 30 kt less than CAS.

## Task

Charts for $\Delta V_C = V_C - V_E$ are available. Nevertheless, we want to produce a Compressibility Correction Chart (CCC) ourselves. The following sub-tasks should be considered:

- Derive the equation to calculate relative pressure in the troposphere and the stratosphere of the International Standard Atmosphere (ISA).
- Derive the equation to calculate the compressibility correction.
- Explain how to calculate all parameters for a CCC with a spreadsheet.
- Write a user guide for your spreadsheet.
- Compare your results with other publications on the topic.
- Compare your exact results with rules of thumb.

The report has to be written in English based on German or international standards on report writing.

Detailed advise for the project:

The FM-Script from Trevor Young has all necessary equations. It is supplemented by Unterlagen zur Vorlesung Flugmechanik 1. Task is to produce a plot of the Compressibility Correction Chart. $\Delta V_C = V_C - V_E$. $V_C$ is the input value (x axis). $V_E$ is calculated from [1.4-20] (from **page 25**) as function of $V_C$ . Relative pressure, $\delta = f(h)$ from "1.2.3 Pressure and Density in the Standard Atmosphere". Altitude, $h$ is taken as parameter producing the various curves in the Compressibility Correction Chart. See also Example 1.3 in the FM-Script from Trevor Young and consider $\Delta V_C = V_C - V_E$. Plotting can be done with a spreadsheet.

More difficult to produce is the Compressibility Correction Chart with Mach number, $M$ as parameter producing the various curves. This is the way forward: $\Delta V_C$ is calculated with [1.4-20] (from **page 24**) as function of $M$. Relative pressure, $\delta = f(h)$. $V_C$ as value for the x-axis is obtained from $V_C = \Delta V_C + V_E$ and $V_E = M\, a_0\, \delta^{1/2}$ [1.4-19]. Values for the x-axis and the y-axis are calculated, stored and subsequently used for the plot.

The report should give an introduction into the topic similar to the section "Calibrated Airspeed" from FM-Script by Trevor Young. It should show the derivation of the equation used to produce the plot. A literature review should point to other publications, in which the production of the Compressibility Correction Chart is explained. One such example is Walter Bislin. Please note also the contribution of Dennis Lucht and his check of the rule of thumb (ROT) based on two equations:

$V = 6\ \mathrm{FL}/10 + V_C + T_T$ (in kt, FL: Flight Level, $T_T$ in °C) and

$V = V_C$ + 2% of $h$/1000 ft (valid only for low level and low speed).