How Accurate are Your Experimental Data? — A More Accessible Methodology for Uncertainty Evaluation Based on the GUM

Luca Bernardini[1, S], Mark McLinden[2], Xiaoxian Yang[1] and Markus Richter[1, C]

[1] *Applied Thermodynamics, Chemnitz University of Technology, Chemnitz, Germany*
[2] *Applied Chemicals and Materials Division, National Institute of Standards and Technology, Boulder, U.S.A.*
m.richter@mb.tu-chemnitz.de

Ensuring accurate evaluation of experimental uncertainty is most important when reporting experimental procedures and data. It serves as the cornerstone for the validation and overall reliability of the presented work. Additionally, uncertainty analysis and a detailed investigation of the uncertainty contributions aid with evaluating the experimental system, allowing for the identification of possible targeted improvements. However, in some cases, the evaluation of the uncertainty can be challenging, especially when applying the method described in the Guide for Evaluating and Expressing Uncertainty in Measurement (GUM), based on partial derivatives of the working equations [1]. As the data analysis of a system becomes more detailed, a more significant number of uncertainty contributions come into play, extending the complexity of the uncertainty calculation. Furthermore, some experimental systems might rely on several non-linear equations, rendering the analysis of partial derivatives nearly impossible (JCGM, 100:2008, chapter 5.1.2. NOTE). In this work, we present a methodology for evaluating uncertainty. This method is readily applicable to systems of various degrees of complexity. It consists of two steps: (1) estimate each uncertainty contribution of the system based on GUM (JCGM, 100:2008, chapter 4), and then (2) determine the sensitivity of the calculated results to variations in each of the input measurands in turn, thus replacing the partial derivatives of the GUM with a purely numerical approach. The sensitivity analysis method consists of running as many mathematical iterations of the working equations as the number of uncertainty contributions. For each iteration, one uncertainty contribution adds to the respective measured, estimated, or assumed value. A new distorted value of the output under consideration is obtained, and its squared difference from the original value is calculated. The combined standard uncertainty u_C is estimated with the square root of the sum of all these squared differences. This methodology provides a simplified approach to evaluating experimental uncertainty and bypasses the complexity of partial derivatives that often prevents researchers from performing accurate uncertainty analyses. The sensitivity analysis method has been shown to be reliable, easy to use, and fast, and provides comparable results to the method described by GUM.

References

1. JCGM, J. 100: 2008 (GUM 1995 with minor corrections) Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement. Joint Committee for Guides in Metrology, 2008, 19.