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Recommended Practice

Calibration of Subsonic and Transonic Wind Tunnels

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Sponsor

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Abstract

The calibration of a wind tunnel is a necessary, yet often neglected, process needed to ensure accurate and repeatable test data. In general, a wind tunnel calibration program encompasses many related topics—basic operating condition calibration, flow quality mapping, wall interference, and model blockage corrections are all topics that can be addressed as part of a tunnel calibration program. However, it is not practical to address all of these topics in a single document, so the scope of this recommended practice has been defined as the empty test section calibration of subsonic and transonic wind tunnels. This American Institute of Aeronautics and Astronautics (AIAA) Recommended Practice is intended to (1) provide an overview on the calibration of subsonic and transonic wind tunnels and (2) provide a basis for commonality within the wind tunnel community in the area of wind tunnel calibration. This document is a compilation of input from several wind tunnel operators and users that summarizes the best practices and recommendations from these experts.

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Foreword

Wind tunnels are the primary source of test data for basic aerodynamic research and for the design and development of aircraft, aircraft components (including propulsion systems), launch vehicles and land vehicles. Since the 1960's, tens of thousands of wind tunnel test hours have usually been required to complete the development and evaluation of a new aircraft. Because of the advances in instrumentation and data systems that provide more accurate measurement of flow parameters and because of the increased sensitivity of aerodynamic and propulsion system performance to wind tunnel flow quality, the accurate calibration of wind tunnels has become progressively more important. Without detailed knowledge of the wind tunnel operating conditions and flow quality, it is impossible to provide reliable and accurate test data to support the needs of test customers.

In the past, there have been workshops and general meetings to discuss issues pertaining to wind tunnel calibration, but in general, no closure or final recommendations were produced from these exercises. To provide a means of closure on calibration issues, the AIAA Ground Testing Technical Committee (GTTC) formed a working group on wind tunnel calibration methodology. This working group was chartered to bring together wind tunnel calibration experts from various Government, industry, and university organizations to share information on calibration techniques and to ultimately make recommendations on preferred methods for wind tunnel calibration.

Because of the large variance in wind tunnel characteristics across facilities (e.g., Mach number range, size and type of facility, types of testing, model blockage effects, etc.), an exhaustive treatment of all pertinent calibration issues was not practical. Therefore, the working group focused on a subset of wind tunnels and test ranges. On the basis of discussions with wind tunnel users and operators from within the GTTC, the scope of the Wind Tunnel Calibration Methodology Working Group was limited to the empty test section calibration of subsonic and transonic wind tunnels. For this exercise, subsonic wind tunnels have a test section Mach number capability up to 0.5, and transonic tunnels up to 1.5. The working group decided to classify this document as a Recommended Practice because the variety of wind tunnels and types of testing conducted in each tunnel make it difficult to define standards that can be directly applied in all instances. Instead, general recommendations are made on hardware, methodologies, and philosophy such that each reader can determine the best calibration program for his or her situation. This document deals mainly with steady-state measurements. It does not address such issues as wall interference, support interference, model size, or unsteady measurements. This is not to minimize the importance of these issues, since they must be addressed for each proposed wind tunnel test. However, many of these issues are covered in detail in other reference documents.

In order to facilitate the exchange of information between the member organizations and to build a database on wind tunnel calibrations, each organization wrote a summary report on their calibration procedures. The information in these summary reports became the building blocks for constructing this Recommended Practice.

The members of the GTTC Wind Tunnel Calibration Methodology Working Group were

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On the recommendation of the Wind Tunnel Calibration Methodology Working Group, the following knowledgeable individuals reviewed the document and provided valuable critique:

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This document was approved by the AIAA Ground Testing Technical Committee (Mr. Allen Arrington, chairman) in January 2003.

The AIAA Standards Executive Council (Mr. Phil Cheney, chairman) approved the document in September 2003.

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Dedication

The Wind Tunnel Calibration Methodology Working Group dedicates this document in memory of Frank Wright, formerly of the Boeing Company. Frank was not only an original member of the working group, but was also among those originally consulted on the formation of this group. Frank's years of knowledge regarding wind tunnel testing and his insightful comments on topics relating to calibration were particularly important as the group began drafting this document.

1 Executive summary

The purposes of this document are (1) to provide an overview of the calibration of subsonic and transonic wind tunnels and (2) to provide a basis for commonality within the wind tunnel community in the area of wind tunnel calibration. Various standards have been developed over the years in the aeronautics industry, many of which pertain to ground testing. These standards have made it easier to share information and hardware, and have allowed the community to improve its overall effectiveness. This document, however, is not intended to set standards for wind tunnel calibration. Details of calibrating a wind tunnel vary from facility to facility according to the type of tests conducted, the operating envelope of the tunnel, and the physical constraints of the facility, which makes having a rigid definition of calibration procedures inappropriate. Instead, this document provides a set of recommended practices that the reader can use to develop a complete tunnel calibration program.

This document focuses on general calibration practices and principles that should be incorporated into the calibration of any tunnel. It provides recommendations on calibration hardware and instrumentation based on the current knowledge of the authors, along with a list of references that readers can use to develop detailed calibration schemes for their tunnels. Detailed examples have been included to provide insight into the current calibration activities at existing wind tunnel facilities. In addition, this document brings to light topics such as statistical quality control that have only recently been applied to tunnel calibration.

This guide strongly recommends that wind tunnel calibrations become a regular part of the operational cycle for any wind tunnel. A planned schedule of calibration tests should be created and executed to ensure that the wind tunnel is operating properly. Beyond this baseline requirement, planned calibration tests offer the advantage of constructing an extensive database describing the tunnel operation, which can be very useful in determining the cause of changes in a flow field. In short, wind tunnel calibrations should be thought of as a regularly scheduled maintenance activity or diagnostic test. Instead of a series of disconnected tests, the calibration activities should take the form of an ongoing test program.

Properly planned, recurring, and well-documented calibrations of a wind tunnel provide several benefits to the tunnel operator and end user.

- They ensure that the wind tunnel is operating as expected and are useful in identifying problems in the wind tunnel circuit.
- They provide potential customers with a documented assessment of the tunnel calibration and are essential in determining overall data quality.
- They provide data essential for interpretation and correction of test data.
- They provide archival documentation of tunnel operating conditions, so that modifications to the wind tunnel may be assessed for their impact on the operating conditions.
- They aid in establishing statistical process control on wind tunnel test data by providing a database of wind tunnel parameter variability.
- They aid in identifying data anomalies that are attributable to the wind tunnel itself, not to the variability in the calibration process.
- They may indicate, by comparison with previous calibrations, that portions of the wind tunnel circuit or instrumentation are in need of repair or recalibration.
- They facilitate tunnel-to-tunnel data comparisons.

Since calibration is considered a critical item in the health monitoring of a wind tunnel, this guide recommends that experienced personnel be assigned to the execution of calibration tasks. In instances where the calibration tests are perceived as routine, they are commonly used as training exercises for