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Recommended Practice

Calibration and Use of Internal Strain-Gage Balances with Application to Wind Tunnel Testing

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Sponsored by

American Institute of Aeronautics and Astronautics

Abstract
This document provides a recommended method for calibration of internal strain-gage balances used in wind tunnel testing. The practices include terminology, axis system definition, balance calibration methods, matrix, and documentation. Use of this document will facilitate the exchange of information among users, suppliers, and other interested parties.

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Foreword

Internal balances are the mainstay instrument used in nearly every wind tunnel test to measure the aerodynamic loads on the test article. For the most part, each facility designs, fabricates, calibrates, and utilizes internal balances in near seclusion. However, with decreasing budgets and customers using multiple facilities, the time had arrived for collaboration on the design, use, calibration, and uncertainty estimation for internal strain-gage balances to begin. The concept of forming a working group for internal balances originated from discussions among individuals from the Arnold Engineering Development Center, the National Aeronautics and Space Administration facility at Langley Research Center, and the Boeing Commercial Airplane Group. The discussions also revealed that there was considerable skepticism concerning the willingness to share information and the ability to reach consensus among the individuals working in the area of internal balances. However, despite the skepticism, it was decided that the working group concept should go forward with the purpose of sharing information and developing recommended practices.

The Ground Testing Technical Committee (GTTC) of the American Institute of Aeronautics and Astronautics (AIAA) was asked to sponsor a working group on internal balance technology. Upon approval, the Internal Balance Technology Working Group (IBTWG) was formed under the auspices of the GTTC. The objective of the IBTWG was to share information on, and experiences with, all facets of internal balances and to develop recommended practices that would allow the facilities to work together to advance the state of the art. The working group's membership consisted primarily of individuals from organizations that calibrate and use internal balances.

One of the early issues that had to be addressed was the working group's membership. Invitations to the first meeting were made to individuals from facilities in the U.S. and Canada. However, during the time of the first meeting, several European organizations expressed an interest in participating in the working group. After considerable debate, the initial invited members agreed that achieving consensus was going to be a difficult enough task among the current members and that expanding the membership might impede the group's progress, possibly to the point of being ineffective. The initial members agreed that the current group be limited to North American participation, but would support the development of a European working group if requested. Then, once recommended practices had been developed in both groups, representatives of each group could meet to develop a mutual set of recommended practices. As of the publication date of this document, a temporary UK working group was formed; however, a European working group had yet to be formed.

The following objectives were set as goals for the working group:

1. Provide a forum for the members to share information on the methodologies and capabilities for internal strain-gage balances. (accomplished and has been very successful)
2. Recommend a calibration matrix format that can be utilized in all of the testing facilities. (accomplished)
3. Develop general guidelines for selecting a balance type and the extent of calibration necessary to meet the objectives of a particular wind tunnel test. (some discussion but not accomplished)
4. Develop a recommended balance calibration uncertainty methodology that is in agreement with existing uncertainty standards (AGARD AR-304 and AIAA S-071A-1999). (partially addressed)
5. Develop methods of accounting for weight tare adjustments (both calibration and testing) that are accepted by the members. (accomplished for calibration only)
6. Investigate new methodologies for the design, attachment, and calibration of internal balances. (not addressed)
7. Develop and publish a Recommended Practices document for internal strain-gage balance methodologies, including an adjustment methodology for thermal effects on balances.

(accomplished with the publication of this document, excluding thermal effects. Although thermal effects have a large affect on a balance, they are not included here since the existing methodologies were so diverse and there did not appear to be a time effective solution to the issue.)

Note that the objectives do not include the implementation of any recommended practices, only the development. This is a result of most of the membership not being in positions in their organizations where they can decide such issues. However, all members agreed that they would promote the implementations of the recommended practices at their facilities.

The working group made excellent progress in three areas: the exchange of information, which includes developing open communications and trust among the members; documentation of the balance technology in use at the member organizations; and the establishment of recommended practices. These efforts will benefit the wind tunnel testing community as a whole, as the recommended practices will improve understanding and communication between facilities and provide the potential to mitigate test costs, and improve the quality of test data.

The following officers and members have provided dedicated support, contributions, and leadership to the AIAA/GTTC Internal Balance Technology Working Group. Their efforts have resulted in the development of this Recommended Practice.

David Cahill	Chair, Sverdrup Technology Inc, AEDC Group
Nancy Swinford	Secretary, Lockheed Martin Space Systems Co.
Allen Arrington	Secretary, QSS Group Inc., NASA Glenn Research Center
Dennis Booth	Allied Aerospace, GASL Division, Force Measurement Systems
Richard Crooks	Allied Aerospace, Flight Systems Division
Robin Galway	RobGal Aerotest Consulting (Retired IAR/NRC)
Andrew Garrell	Veridian Engineering (formerly Calspan)
Don Hamilton	Institute for Aerospace Research/NRC
Steve Hatten	The Boeing Company
Mark Kammeyer	The Boeing Company
Chris Lockwood	Sverdrup Technology Inc., Ames Group
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Paul Roberts	NASA Langley Research Center
Mat Rueger	The Boeing Company
Lew Scherer	Northrop Grumman
Frank Steinle	Sverdrup Technology Inc., AEDC Group
Jim Thain	Institute for Aerospace Research/NRC
Johannes van Aken	Aerospace Computing, NASA Ames

Doug Voss	The Boeing Company
Jimmy Walker	Lockheed Martin LSWT
Frank Wright	The Boeing Company (Deceased)
Pat Whittaker	NASA Ames Research Center

The AIAA Ground Testing Technical Committee (Mr. Dan Marren, Chairperson) approved the document for publication in January 2001.

The AIAA Standards Executive Council (Phil Cheney, Chairman) accepted the document for publication in September 2003.

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Dedication

The Internal Balance Technology Working Group has dedicated this Recommended Practice in the memory of Mr. Frank L. Wright, formerly of The Boeing Company. Frank was instrumental in the formation of this working group and the sharing of his wind tunnel testing experience, knowledge, and insight through his participation were instrumental in its success.

1 Introduction

1.1 Scope

This document provides a recommended method for calibration of internal strain-gage balances used in wind tunnel testing. The practices include terminology, axis system definition, balance calibration methods, matrix, and documentation. Use of this document will facilitate the exchange of information among users, suppliers, and other interested parties.

1.2 Purpose

Internal strain-gage balances are used extensively to measure the aerodynamic loads on a test article during a wind tunnel test. There has been little collaboration on internal balances; consequently, several types of balances, calibration methods, calibration matrices, tare adjustments, and uncertainty evaluations have evolved. The purpose of the group was to pool their information and experiences to enhance each other's capabilities and to develop recommended practices for the use, calibration, tare adjustment, and uncertainty evaluation of internal balances.

The acceptance and universality of a recommended practice is dependent on how well the organizations involved represent the industry. In this instance the Internal Balance Technology Working Group had membership and participation from all of the major wind tunnel facilities and aircraft developers in North America. The fact that these organizations were able to agree on the recommended practices contained in this document will provide the weight necessary to instill their adoption, not only in North America but many of the recommended practices will be adopted by organizations around the world. The members of the working group represented the following organizations:

Arnold Engineering Development Center (AEDC)	Allied Aerospace (formerly Micro Craft)
The Boeing Company	NASA Ames Research Center (ARC)
Veridian Engineering (formerly Calspan)	NASA Glenn Research Center (GRC)
Institute for Aerospace Research, Canada (IAR)	NASA Langley Research Center (LaRC)
Lockheed Martin	Northrop Grumman

This document presents the reader with a clear means of designating balance types and gage nomenclature, a concise methodology (including tare corrections) for balance calibration, the reporting of the balance calibration matrix, and for the reporting of statistical and calibration specific information. An example of the balance calibration data reduction process is available for downloading on the GTTC website. The GTTC website can be accessed via the *Technical Committees* link on the AIAA website at www.aiaa.org. This document also presents guidelines for the user in preparing a calibration load schedule and for selecting coefficients to include in the math model as well as presenting the benefits of using global regression for the computation of balance calibration coefficients. Finally, a data reduction method is presented for calculating the component loads from the bridge readings measured during a wind tunnel test.

1.3 Cautions and Limitations

The following cautions and limitations are provided as an aid in understanding and applying the recommended practices:

1. Although the working group recommends a 6x96 calibration matrix format, it is recognized that all of the terms may not be present for any single calibration. The matrix format does incorporate all the terms that are in use by the members of the working group. As noted in the text, terms should only be included in the matrix which directly correspond to loadings applied during the calibration.