AIAA
R-091A-2020

Recommended Practice

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

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

Sponsored by

American Institute of Aeronautics and Astronautics

Approved

3 March 2020

Abstract

This document provides a recommended method for calibration and use of internal strain-gage balances 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

In 2003 a committee of The Ground Testing Technical Committee (GTTC) of the American Institute of Aeronautics and Astronautics (AIAA) published the highly successful AIAA R-091 2003 Calibration and Use of Internal Strain-Gage Balance with Application to Wind Tunnel Testing [Ref. 1]. In the seven years following that publication several additional issues have come to the attention of the balance community and in 2010 the GTTC and AIAA authorized a new Committee on Standards (CoS) to revise the original standards document.

One of the early issues that had to be addressed was the working group's membership. For various reasons the first committee was limited in membership to the US and Canada. It was desired to open the membership in the new CoS to all nations. After overcoming several issues, the CoS was formed and was open to all individuals. This is an excellent result but could potentially result in changes to the original recommended practices in addition to addressing the new topics of interest.

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

1. Review the recommended math model or calibration matrix (6x96) and update it to a smaller or larger matrix based on the group's investigations. Provide guidance/ formulas, on selecting the appropriate subset matrix for a particular balance and calibration load schedule.
2. Investigate uncertainty estimate calculations to provide better estimates of the balance calibration uncertainty. This will include items such as separating the balance uncertainty from the calibration system.
3. Provide recommendations for thermal effects on balance performance. This will include physical and numerical compensation techniques for zeros and calibration coefficients. The initial focus will be on steady state temperatures and followed with temperature gradient recommendations.
4. Investigate and provide recommendations on how to include pressure effects (due to internal balance flow) on the balance performance (calibration).
5. Develop metrics for evaluating a balance's condition to help determine if it needs to be calibrated and the level of calibration needed.
6. Review the current axis system and determine if it is appropriate to shift to an international standard.
7. Provide recommendations on wind tunnel check loads that will assist in transferring the calibration uncertainty to the facility where the balance is used.

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 Internal Balance CoS. Their efforts have resulted in the development of this revision to the Recommended Practice.

Ray Rhew	Chair, NASA Langley Research Center
David Cahill	Vice-Chair, Sierra Lobo Inc.
Henry Bennett	The Boeing Company
Dennis Booth	Calspan Force Measurement Systems
Robin Galway	RobGal Aerotest Consulting (Retired IAR/NRC)
Mark Kammeyer	The Boeing Company
Stan Richardson	Sverdrup Technology Inc., AEDC Group
Lew Scherer	Northrop Grumman
Johannes van Aken	Aerospace Computing, NASA Ames
Norbert Ulbrich	Jacobs Technology, NASA Ames
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Koen Artois	German-Dutch Wind Tunnels (DNW)
Shinji Nagai	Japan Aerospace Exploration Agency (JAXA)
Klaus Hufnagel	Technical University of Darmstadt (TUD)
David Yoder	Arnold Engineering and Development Center (AEDC)
Daniel Lewis	Arnold Engineering and Development Center (AEDC)
Steve Buchholz	Jacobs Technology, NASA Ames
Ken Toro	NASA Langley Research Center
Peter A. Parker	NASA Langley Research Center

The AIAA Standards Steering Committee accepted the document for publication in March 2020.

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Recognition and Dedication for AIAA R-091 2003

The following committee officers and members responsible for the original standard are recognized here for their dedicated support, contributions, and leadership.

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	Calspan
Don Hamilton	Institute for Aerospace Research/NRC
Steve Hatten	The Boeing Company
Mark Kammeyer	The Boeing Company
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Phillip Luan	Sverdrup Technology Inc., Ames Group
Ray Rhew	NASA Langley Research Center
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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 committee dedicated the original Recommended Practice in the memory of Mr. Frank L. Wright, formerly of The Boeing Company. Frank was instrumental in the formation of this committee 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 many of the major wind tunnel facilities and aircraft developers in the world. 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 by organizations around the world. The members of the working group represented the following organizations:

Arnold Engineering Development Center (AEDC)	Triumph Aerospace
The Boeing Company	NASA Ames Research Center (ARC)
Calspan	NASA Glenn Research Center (GRC)
Institute for Aerospace Research, Canada (IAR)	NASA Langley Research Center (LaRC)
Lockheed Martin	Northrop Grumman
European Transonic Wind Tunnel (ETW)	German-Dutch Wind Tunnels (DNW)
Japan Aerospace Exploration Agency (JAXA)	Jacobs Technology

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 should not be present for any single calibration. The matrix format does incorporate all