



**NBS HANDBOOK 145**

U.S. DEPARTMENT OF COMMERCE/National Bureau of Standards

# **Handbook for the Quality Assurance of Metrological Measurements**

**John K. Taylor and Henry V. Oppermann**

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he National Bureau of Standards<sup>1</sup> was established by an act of Congress on March 3, 1901. The Bureau's overall goal is to strengthen and advance the nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau's technical work is performed by the National Measurement Laboratory, the National Engineering Laboratory, the Institute for Computer Sciences and Technology, and the Institute for Materials Science and Engineering.

## *The National Measurement Laboratory*

Provides the national system of physical and chemical measurement; coordinates the system with measurement systems of other nations and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce; provides advisory and research services to other Government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides calibration services. The Laboratory consists of the following centers:

- Basic Standards<sup>2</sup>
- Radiation Research
- Chemical Physics
- Analytical Chemistry

## *The National Engineering Laboratory*

Provides technology and technical services to the public and private sectors to address national needs and to solve national problems; conducts research in engineering and applied science in support of these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; develops engineering data and measurement capabilities; provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user. The Laboratory consists of the following centers:

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- Manufacturing Engineering
- Building Technology
- Fire Research
- Chemical Engineering<sup>2</sup>

## *The Institute for Computer Sciences and Technology*

Conducts research and provides scientific and technical services to aid Federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in Government operations in accordance with Public Law 89-306 (40 U.S.C. 759), relevant Executive Orders, and other directives; carries out this mission by managing the Federal Information Processing Standards Program, developing Federal ADP standards guidelines, and managing Federal participation in ADP voluntary standardization activities; provides scientific and technological advisory services and assistance to Federal agencies; and provides the technical foundation for computer-related policies of the Federal Government. The Institute consists of the following centers:

- Programming Science and Technology
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Conducts research and provides measurements, data, standards, reference materials, quantitative understanding and other technical information fundamental to the processing, structure, properties and performance of materials; addresses the scientific basis for new advanced materials technologies; plans research around cross-country scientific themes such as nondestructive evaluation and phase diagram development; oversees Bureau-wide technical programs in nuclear reactor radiation research and nondestructive evaluation; and broadly disseminates generic technical information resulting from its programs. The Institute consists of the following Divisions:

- Ceramics
- Fracture and Deformation<sup>3</sup>
- Polymers
- Metallurgy
- Reactor Radiation

<sup>1</sup>Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Gaithersburg, MD 20899.

<sup>2</sup>Some divisions within the center are located at Boulder, CO 80303.

<sup>3</sup>Located at Boulder, CO, with some elements at Gaithersburg, MD.

# Handbook for the Quality Assurance of Metrological Measurements

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## PREFACE

This handbook is the third of a series developed by the National Bureau of Standards for use in the management of the national weights and measures measurement system. The other two publications are:

NBS Handbook 143, "State Weights and Measures Laboratories, Program Handbook," and

NBS Special Publication 686, "State Weights and Measures Laboratories, Program Description and Directory."

State weights and measures laboratories are in the forefront in assuring equity in the marketplace. A key to their success in that role is their ability to provide high accuracy calibrations and measurements. Those calibrations and measurements must be traceable to the national standards and must be in statistical control. Statistical control depends on a quality measurement assurance program which, in turn, depends on a competent staff, and adequate facilities and equipment.

This handbook provides the basis for the quality measurement assurance program by documenting good laboratory practices (GLPs), good measurement practices (GMPs), and standard operations procedures (SOPs). Those following the guidance in this handbook will be assured that their measurement data are properly evaluated and limits of random and systematic error assigned.

State laboratories are expected to study and use the material in this handbook, tailoring the material to fit their unique requirements. Although the handbook was written with the specific needs of the state laboratories in mind, it should be useful to the wider audience of laboratories engaged in high accuracy metrological measurements.

The authors encourage the users to comment on their experience in the use of this material so that it can be improved.

Albert D. Tholen  
Office of Weights and Measures  
National Bureau of Standards



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The practices and procedures presented in the handbook are based largely on the research and experience of numerous scientists at NBS, both named and unnamed, whose individual and collective goals have been to develop and utilize metrological procedures of the highest quality to serve the ever demanding needs of modern technology.

We are especially grateful to Mrs. Carroll Croarkin and Dr. Keith Eberhardt who critically reviewed the statistical aspects of the manuscript and made many helpful suggestions for the development of the uncertainty statements in the procedures.

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UNITED STATES DEPARTMENT OF COMMERCE  
National Institute of Standards and Technology  
(formerly National Bureau of Standards)  
Gaithersburg, Maryland 20899

June 2, 1989

MEMORANDUM FOR: Users of NBS Handbook 145

From: Henry Oppermann

*Henry*

Subject: Errata Sheets/Replacement Pages

Attached are replacement pages for NBS Handbook 145, "Handbook for the Quality Assurance of Metrological Measurements." These pages are to replace pages that contained errors in the original publication. The page numbers and the errors that have been corrected are summarized below.

- Page SOP 2-6 The words "at 0 °C" were added to the second sentence on the last paragraph to complete the density statement for 8.4 g/cm<sup>3</sup>.
- Page SOP 2-9 The subscript in the numerator of the numerator of equation 5 for the density of air at the time of balance calibration and the subscript in the definition of the symbols under the equation has been changed from a "c" to an "A".
- Page SOP 2-11 Another set of brackets were added to equation 7.
- Page SOP 15-5 The plus and minus signs associated with the air density times the volumes of the standards equation in 3.2 were reversed and has a significant effect on the value computed for the volume of the standard.
- Page 8.3 The square root sign in the formula at the top of the page was omitted in the original publication and has been added.
- Page 9.10 The water density for 29 °C was changed to correct a typographical error.

The error in the signs on page SOP 15-5 has a significant effect on the final result. Anyone who has used this equation for a calibration should repeat the calculation using the corrected equation and report a new value for the standard if it changes the result significantly relative to the uncertainty statement. I regret any inconvenience this may have caused.

If you are aware of other users of this handbook who have not received these replacement pages, please alert them to the availability of these pages. Copies may be obtained by calling the Office of Weights and Measures at (301) 975-4004.

SOP 11-9

11-10

11-11

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March 29, 1990

