National Institute of
Standards and Technology
U.S. Department of Commerce

Specifications and Tolerances

for Reference Standards and Field Standard Weights and Measures

NIST Handbook 105-1

Specifications and Tolerances for Field Standard Weights

2019

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https://doi.org/10.6028/NIST.HB.105-1-2019

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Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures

Specifications and Tolerances for Field Standard Weights

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https://doi.org/10.6028/NIST.HB.105-1-2019

May 2019

U.S. Department of Commerce
Wilbur L. Ross, Secretary

National Institute of Standards and Technology
Dr. Walter Copan, NIST Director and Under Secretary of Commerce for Standards and Technology

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References 1990 Edition for Field Standards in service prior to January 1, 2020.

Certain commercial entities, equipment, or materials may be identified in this document to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

National Institute of Standards and Technology Handbook 105-1, 2019 Edition
Natl. Inst. Stand. Technol. Handb. 105-1, 2019 Ed., 13 pages (May 2019)

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON
For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401-9325

Preface

NIST Handbook 105-1 contains specifications and tolerances establishing minimum requirements for standards used by State and local Weights and Measures officials in the regulatory verification of scales and other weighing devices used in quantity determination of materials sold by weight. Other users may find this handbook helpful in the design of field standard weights, but the requirements should not be considered mandatory for special applications outside of the scope of regulatory Weights and Measures.

Document History and Changes

NIST Handbook 105-1 has been updated infrequently. The three most recent revisions prior to this edition were completed in 1969, 1972 and in 1990. In each revision changes were made to address issues that had been identified since the prior revision. Weight designs, materials, and tolerances were some of the changes.

In this 2019 edition, NIST Handbook 105-1 directs the user to a much broader choice of mass standards that must be properly selected to ensure full compliance with NIST Handbook 44 Appendix A Fundamental Considerations is maintained. The commercial weighing marketplace is changing, and increased use of Class I and Class II commercial weighing devices indicates that the tolerances originally identified in NIST Handbook 105-1 (approximately 0.01 % of nominal) are no longer adequate for the testing of all commercial weighing systems. Mass standards of accuracy classes such as OIML R111 Class F_1 and ASTM E617 Class 2 are increasingly required for calibration of some commercial weighing systems. As NIST Handbook 105-1 identifies the mass standards that are suitable for Weights and Measures field use, and ASTM E617 and OIML R111 both identify a wide range of mass standard tolerances, users are now directed to those documentary standards for selection of field standard weights.

The 1990 edition of NIST Handbook 105-1 will be maintained as written in 1990 and made available by NIST Office of Weights and Measures upon request, to provide historical reference for calibration of NIST Class F weights placed in service prior to January 1, 2020. NIST Class F field standards should not be procured for legal metrology (Weights and Measures) use after January 1, 2020.

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FOR REFERENCE STANDARDS AND FIELD STANDARD
WEIGHTS AND MEASURES

1. Specifications and Tolerances for Field Standard Weights

These specifications and tolerances establish the minimum requirements for Field Standards used by State and local Weights and Measures officials and others in the regulatory verification of weighing devices used in quantity determination of commodities sold by weight. Non-Weights and Measures users may find this handbook helpful in the design of field standard weights, but the requirements should not be considered mandatory for special applications outside of the scope of regulatory Weights and Measures.

Key words: field standard weight, weight, standard, NIST Class F, tolerance, maximum permissible error.

Introduction

Field standard weights are used primarily to test commercial weighing devices for compliance with commercial requirements. Use of these field standards at all appropriate levels of manufacture, distribution, and Weights and Measures inspection will help promote accuracy and uniformity in commerce. The breadth of topics in this handbook is intended to provide information for manufacturers, calibration staff, Weights and Measures officials, and other end users. References are provided when additional information may be useful to the reader.

1 Scope

1.1 "Field Standard" Classification

These specifications and tolerances are limited to Field Standard Weights. The field standards covered by this publication are intended to be used by Weights and Measures officials. Manufacturers and distributors of scales, load cells, and other weighing devices may find these specifications and tolerances useful. Use of these standards at all appropriate levels of manufacture, distribution, and Weights and Measures inspection will help promote accuracy and uniformity in commerce.

The terms "weight", "mass standard", and "mass" as used in this publication refer to all sizes in general. U.S. Customary units will be used hereafter to reflect the nominal masses in common usage in the United States.

1.2 Retroactivity

These specifications are not intended to make obsolete those field standards manufactured to comply with NIST Handbook 105-1 (1990). However, all new field standard weights placed in service after January 1, 2020, must meet the requirements of Handbook 105-1 (2019) prior to approval for regulatory Weights and Measures (legal metrology) use.

Field standard weights manufactured to meet prior specifications may be used provided they 1) comply with the applicable NIST, ASTM, or OIML requirements, 2) maintain the specified tolerances, 3) their performance is adequate to meet NIST Handbook 44 fundamental considerations

(i.e., the correction plus the measurement uncertainty does not exceed one-third of the tolerance for the device being tested). Existing NIST Class F field standards are considered acceptable for use when the requirements of the Fundamental Considerations are met (normally Class III, IIIL, and IV weighing devices.

NOTE: NIST Handbook 105-1 (1990) will be maintained and provided by NIST Office of Weights and Measures (OWM) upon request to provide historical perspective and to ensure that design and tolerance information is maintained for field standards that were manufactured and procured to that version of this specification.

Reclassifying existing NIST Class F field standards to one of the other specifications may be considered only if all specifications (e.g., design, density, markings, materials) and tolerances are fully assessed and found to fully comply with the alternative standard.

NOTE: Due to known differences among the documentary standards and the difficulty of ensuring a full evaluation and compliance of all physical characteristics, NIST OWM strongly recommends that Class F field standards under the requirements of NIST Handbook 105-1 (1990), or earlier, not be reclassified.

1.3 Future Designs

These specifications are not intended to limit innovation made possible by advances in technology or changes in the commercial field devices they are used to test. All design revisions should be evaluated by NIST OWM for accuracy, stability, and suitability for the intended legal metrology applications. Approved design revisions may be included in future revisions of this document.

2 Reference Documents

2.1 American Society for Testing and Materials (ASTM)[1]

2.1.1 ASTM E617 – 18 (2018) or latest revision.

2.2 International Organization of Legal Metrology (OIML)[2]

2.2.1 International Recommendation, OIML R 111-1, Edition 2004 (E), weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3}, and M_3, Part 1: Metrological and technical requirements or latest revision.

2.3 National Institute of Standards and Technology (NIST), Office of Weights and Measures (OWM)[3]

2.3.1 Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices, published annually, (latest edition).

[1] American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2951, USA. WEB Site: http://www.astm.org/

[2] International Organization of Legal Metrology (Organisation Internationale de Métrologie Légale, OIML), 11, rue Turgot, F-75009 Paris, France. WEB Site: http://www.oiml.org/

[3] National Institute of Standards and Technology (NIST), Office of Weights and Measures (OWM), 100 Bureau Drive Stop 2600, Gaithersburg, MD 20899-2600, USA. WEB Site: https://www.nist.gov/pml/weights-and-measures

2.3.2 NISTIR 6969**,** Selected Laboratory and Measurement Practices, and Procedures to Support Basic Mass Calibrations, (latest edition).

2.3.3 NISTIR 5672, Advanced Mass Calibrations and Measurements Assurance Program for the State Calibration Laboratories, (latest edition).

3 Terminology

Standard. Physical realization or representation of a unit of measure. In the context of this handbook standard may mean a laboratory standard or a field standard.

Tolerance. Maximum permissible error (mpe): extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system.

4 Specifications

Because of the increased use of NIST Handbook 44 Class I and Class II weighing devices as commercial weighing devices, NIST Class F mass field standards having an accuracy of approximately 0.01 % of nominal are not adequate to cover the full range of weighing devices to be tested while maintaining compliance with the requirements of Handbook 44, Appendix A, Fundamental Considerations Associated with the Enforcement of Handbook 44 Codes. For this reason, field officials must have additional weight classifications available to facilitate compliance with paragraph 3.2 Tolerances for Standards of the excerpted requirements of Handbook 44, Appendix A, Section 3 shown on page 11 of this document. To ensure that Weights and Measures field officials have access to adequate standards for testing weighing devices, regardless of weighing device classification, after the maximum permissible error of the weighing device has been calculated, Weights and Measures field officials shall select appropriate mass standards from those listed in one of the following documentary standards:

- ASTM E617, Standard Specification for Laboratory Weights and Precision Mass Standards,
- OIML R111, Weights of classes E_1, E_2, F_1, F_2, M_1, $M_{1–2}$, M_2, $M_{2–3}$ and M_3, Part 1: Metrological and technical requirements.

Table 1: Applications of Weights for Commercial Weighing Device Tests to Maintenance Tolerances

Classification of Weighing Device tested	ASTM Accuracy Classes	OIML Accuracy Classes	NIST 105-1(1990)
Class I	1	F_1	
Class II	1, 2	F_1, F_2	
Class III	3, 4, 5, 6	M_1, M_2, M_{1-2}, M_{2-3}	F
Class III L	3, 4, 5, 6	M_1, M_2, M_{1-2}, M_{2-3}	F
Class IIII	3, 4, 5, 6	M_3	F

The above table indicates the likely accuracy classifications suitable for each scale classification. It is the responsibility of the field official or service agent to verify that the maximum permissible errors of weights used for a specific weighing device test comply with the requirements of the Fundamental Considerations as published in NIST Handbook 44. The suitability evaluation of field standards is typically performed for loads at the top of each tolerance window as those test loads have the most stringent requirement.

NOTE: For example, a Class II weighing device has a maintenance tolerance of one scale division (d) or one verification division (e) at a test load of 5000 d(e). Assuming this equates to a 5 g test load the weighing device tolerance will be ± 0.001 g. Also, assuming the field standard test weights are being used as nominal mass standards, the maximum permissible error of the test weights must be less than one-third of the 0.001 g tolerance or 0.000333 g (0.333 mg). An examination of the MPE tables of OIML R111 shows that at the 5 g test load a Class F1 mass standard would be acceptable having an MPE of 0.160 mg. However, if performing a test to acceptance tolerances where the tolerance would be ½ d(e), the mass standard would be required to have an MPE of 0.167 mg and a Class F1 mass standard having an MPE of 0.160 mg would be acceptable. Alternatively, a 5 g ASTM E617 Class 3 weight having an MPE of 0.18 mg is acceptable for the maintenance tolerance verification and ASTM E617 Class 2 having an MPE of 0.054 mg is acceptable for the acceptance tolerance verification.

4.1 Physical Size

Any nominal mass identified in ASTM E617 or OIML R111 is permitted.

4.2 Size Declaration

As specified in ASTM E617 or OIML R111.

4.3 Identification Markings

As specified in ASTM E617 or OIML R111.

4.4 Material

As specified in ASTM E617 or OIML R111.

4.5 Construction

As specified in ASTM E617, OIML R111 with one limitation: cylindrical weights must be designed for use with the center cylinder axis in a vertical direction. Cylindrical weights designed to be used in a horizontal position are not permitted.

5 Tolerances (Maximum Permissible Errors)

Consult the applicable tables in ASTM E617 or OIML R111.

6 Verification Requirements

6.1 Legal Requirements

The specifications and tolerances identified herein are intended to permit the use of the equipment in normal field-testing operations as standards having nominal values. Weights and measures requirements, including but not limited to, inspection, testing, and sealing by a NIST recognized laboratory, shall be followed.

NOTE: Some States have requirements that are not documented here.

6.2 Traceability

Field standards used for legal metrology shall be traceable to national standards by calibration in a laboratory recognized by NIST Office of Weights and Measures or accredited to ISO/IEC 17025 to calibrate in that parameter, range, and scope as specified by local regulations. Laboratories performing calibrations to establish traceability must comply with the calibration requirements of the applicable ASTM or OIML documentary standard. These requirements include, but are not limited to, laboratory environment, laboratory equipment, calibration method, process uncertainty, and weight design.

6.3 Calibration Certificates

Acceptable accuracy and traceability to national or international standards shall be documented in a calibration certificate using accepted test methods. A calibration certificate must be prepared that complies with NISTIR 6969, SOP 1, Recommended Standard Operating Procedure for Calibration Certificate Preparation which is compliant with ISO/IEC 17025:2017 or the latest revision.

6.4 Initial and Periodic Verification

Field standards shall be verified and calibrated prior to use and recalibrated as often as regulations or circumstances require, especially when damage is known or suspected. Verification requires full assessment of compliance to all specifications and tolerances per ISO/IEC 17025:2017.

NOTE: Field standard calibration intervals are dependent on local Weights and Measures requirements. Field standard mass calibration intervals are often established at 1 year and extended or reduced based on historical evidence up to the limit determined by State or local regulations but should not exceed 5 years. Mass standards made of cast iron and used routinely may require much more frequent calibration due to instability that results from wear of the relatively soft material. Existing Class F, OIML Classes M_1 through M_3, and ASTM Classes 4 through 7 mass standards made of stainless steel usually demonstrate sufficient stability so that longer recalibration intervals may be acceptable; however, intervals must be adjusted based on the stability data that is collected during routine calibrations.

7 Test Methods and References

Field standard weights shall be calibrated as specified following each documentary standard that is referenced. Use of properly selected standard operating procedures from NISTIR 6969 and NISTIR 5672 will normally suffice provided that the proper procedure is selected, and the environment, standards, equipment, methods, and laboratory capabilities specified for the selected procedure are met.

NISTIR 6969, Selected Laboratory and Measurement Practices, and Procedures to Support Basic Mass Calibrations, (latest edition).

NISTIR 5672, Advanced Mass Calibrations and Measurements Assurance Program for the State Calibration Laboratories, (latest edition).

8 Uncertainties

8.1 Legal Applications

Expanded uncertainties (U) of the mass artifact calibration must comply with the requirements of the applicable calibration procedure and documentary standard (typically $U < 1/3$ mpe). Uncertainty of the weighing system calibration must be evaluated according to the Evaluation of measurement data – Guide to the expression of uncertainty in measurement, 2008[4] to ensure that the requirements established by NIST Handbook 44, Fundamental Considerations are maintained.

[4] Evaluation of measurement data – Guide to the expression of uncertainty in measurement, JCGM 100:2008, (GUM 1995 with minor corrections) WEB Site: http://www.bipm.org/en/publications/guides/gum.html

8.2 Excerpt from Handbook 44 - 2019

Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices as adopted by the 103rd National Conference on Weights and Measures 2018.

"Appendix A. Fundamental Considerations Associated with the Enforcement of Handbook 44 Codes

3. Testing Apparatus

3.1. Adequacy.[1] – Tests can be made properly only if, among other things, adequate testing apparatus is available. Testing apparatus may be considered adequate only when it is properly designed for its intended use, when it is so constructed that it will retain its characteristics for a reasonable period under conditions of normal use, when it is available in denominations appropriate for a proper determination of the value or performance of the commercial equipment under test, and when it is accurately calibrated.

3.2. Tolerances for Standards. – Except for work of relatively high precision, it is recommended that the accuracy of standards used in testing commercial weighing and measuring equipment be established and maintained so that the use of corrections is not necessary. When the standard is used without correction, its combined error and uncertainty must be less than one-third of the applicable device tolerance.

Device testing is complicated to some degree when corrections to standards are applied. When using a correction for a standard, the uncertainty associated with the corrected value must be less than one-third of the applicable device tolerance. The reason for this requirement is to give the device being tested as nearly as practicable the full benefit of its own tolerance.

3.3. Accuracy of Standards. – Prior to the official use of testing apparatus, its accuracy should invariably be verified. Field standards should be calibrated as often as circumstances require. By their nature, metal volumetric field standards are more susceptible to damage in handling than are standards of some other types. A field standard should be calibrated whenever damage is known or suspected to have occurred or significant repairs have been made. In addition, field standards, particularly volumetric standards, should be calibrated with sufficient frequency to affirm their continued accuracy, so that the official may always be in an unassailable position with respect to the accuracy of his testing apparatus. Secondary field standards, such as special fabric testing tapes, should be verified much more frequently than such basic standards as steel tapes or volumetric provers to demonstrate their constancy of value or performance.

Accurate and dependable results cannot be obtained with faulty or inadequate field standards. If either the service person or official is poorly equipped, their results cannot be expected to check consistently. Disagreements can be avoided, and the servicing of commercial equipment can be expedited and improved if service persons and officials give equal attention to the adequacy and maintenance of their testing apparatus."

[1] Recommendations regarding the specifications and tolerances for suitable field standards may be obtained from the Office of Weights and Measures of the National Institute of Standards and Technology. Standards will meet the specifications of the National Institute of Standards and Technology Handbook 105-Series standards (or other suitable and designated standards). This section shall not preclude the use of additional field standards and/or equipment, as approved by the Director, for uniform evaluation of device performance.