NIST Handbook 105-1 REVISED! What Now?

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After seeking input from interested parties for over five years, the NIST Office of Weights and Measures (OWM) revised and published NIST Handbook 105-1 (2019) (HB 105-1) *Specifications and Tolerances for Field Standard* Weights in May 2019. 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. NIST OWM has received a number of questions regarding the 2019 edition of HB 105-1. In particular, questions have arisen regarding the continued use of Class F weights.

Background. The 2019 revision of NIST HB 105-1 was brought about by significant changes taking place in the Weights and Measures Field environment. Improvements in technology and changes in the regulated marketplace have resulted in the rapidly increasing number of NIST Handbook (HB) 44 Class I and Class II weighing devices in the commercial marketplace. Typical applications for Class I and Class II are precision and other laboratory weighing; precious metals and gems weighing; and grain test scales.

In 2014, Examination Procedure Outline Number 5 (EPO 5), *Jeweler and Prescription Scales, Part 1*, was updated to address the fact that weights designated under the classification of “NIST Class F” are not adequate to field test Class I and Class II scales. In that EPO, Table 1 provides basic guidance to field staff in selecting mass standards for the test of a commercial scale. While some weights and measures jurisdictions followed such guidance prior to the addition of this table, many weights and measures jurisdictions simply used “Class F” weights to test all commercial weighing devices, including Class I and Class II devices. As the use of these higher accuracy class (Class I and Class II) scales became more common in commercial applications, this prompted the need for field standard weights with a wider variety of classifications. This also required that Weights and Measures field staff be trained in the use of higher weight classifications that cannot be handled with bare fingers. The increased use of higher accuracy weighing devices also requires that more attention be given to the process of calculating and comparing scale tolerances and, field standard weight errors and tolerances to ensure compliance with NIST HB 44 *Fundamental Considerations*.

Excerpt from EPO 5 (2014) Table 1
<u>Mass Standards Required</u>
Class I Scales: OIML E-2, ASTM 1, or standards of greater accuracy.
Class II Scales: OIML F-1, ASTM 3, or standards of greater accuracy.
Class III Scales: NIST Class F, or standards of greater accuracy. Unmarked Scales:
Use standards of the proper level of accuracy that comply with NIST Handbook 44 Fundamental Consideration as detailed in footnote 1.

Status of Class F Weights. There were many significant changes in the NIST HB 105-1 documentary standard, but the most challenging change for users of HB 105-1 seems to be the requirement that no new NIST Class F weights be placed into service for use in testing commercial weighing equipment after January 1, 2020.

[1] In accordance with NIST Handbook 44, Fundamental Considerations Section 3 paragraph 3.2., the combined error and uncertainty of any standard used for testing must be less than one-third the applicable device tolerance. The use of the mass standards indicated in the above table for each of the scale accuracy classes listed will ensure conformance with this fundamental consideration.

Existing NIST Class F field standard weights may continue to be used, provided they demonstrate mass stability and are properly maintained. However, their suitability will still be limited to use as field standard weights for verification of NIST Handbook 44 weighing systems designated as Accuracy Classes III, IIIL and IIII.

Legal Requirements for Field Standard Weights. Retiring HB 105-1 was initially discussed. However, to minimize the impact to the many states and weights and measures jurisdictions who have the specific handbook cited in their legal documents, the revised NIST HB 105-1 has been maintained as a NIST Handbook. Field standard weights, regardless of accuracy classification, must still comply with the requirement of NIST HB 105-1. However, that document now directs the user to one of the following standards for the specifications and tolerances of new weights to be used for weighing device field tests.

- ASTM E617, *Standard Specification for Laboratory Weights and Precision Mass Standards*
- OIML R111-1, International Recommendation, *Weights of Classes E_1, E_2, F_1, F_2, M_1, $M_{1\text{-}2}$, M_2, $M_{2\text{-}3}$ and M_3, Part 1*

Comparing Tolerances Among Standards. As a quick reference, Table 1 of the 2019 edition of NIST HB 105-1 lists the most common weight tolerance classifications that will be used for the various classes of weighing devices. For the purposes of this article and clarity, the table title has been editorially modified and the dates noted in the table; references are to the versions of these documents that are current as of the date of this publication.

Table 1:
Appropriate Test Weight Designations for Tests of Commercial Weighing Devices to Maintenance Tolerances

Class of Weighing Device to be Tested	ASTM E617 Accuracy Classes (2018)	OIML R111 Accuracy Classes (2004)	NIST HB 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, $M_{1\text{-}2}$, $M_{2\text{-}3}$	F
Class IIIL	3, 4, 5, 6	M_1, M_2, $M_{1\text{-}2}$, $M_{2\text{-}3}$	F
Class IIII	3, 4, 5, 6	M_3	F

The field inspector or service technician performing the verification or calibration of the weighing device is responsible for selecting the correct class of field standard weights for the test of a weighing device.

ASTM E617. ASTM E617 Class 6 tolerances are very similar to those of NIST Class F, though they are not the same for all nominal values. Additionally, there are some nominal values for which there is not a Class 6 tolerance specified in this Class. However, ASTM E617 paragraph 4.3 states that "for weight of denominations intermediate between those listed, the maximum permissible error (tolerance) shall be proportional to the values shown." So, even if a nominal value does not have a tolerance value assigned, one can typically be calculated by interpolating between the nominal values that are listed in the table. For example, the most likely encountered nominal value with no specified tolerance is $^{1}/_{32}$ oz, which is equivalent to 0.03125 oz.

Nominal values and tolerances listed ASTM E617 for weights with nominal values adjacent to the value of 0.03125 oz are as shown below:

Nominal Value (oz)	Class 6 Tolerance (mg)*

0.03	0.091
0.03125 ($^1/_{32}$)	(0.091)
0.05	0.091

In this example, the tolerance specified for both the nominal values adjacent to 0.03125 ounces in the table are the same (0.091 mg). Thus, it is permissible to assign a tolerance of 0.091 mg to a test weight with a nominal value of 0.03125 oz.

If there are no bracketing options, then the best one can do is to assume that the tolerance of the next largest published nominal value will continue to those smaller nominal values, but this approach is not always the best as the tolerances may become unreasonably large for very small weights.

Nominal Value (lb)	Class 6 Tolerance (mg)*	Class 6 Tolerance (% of nominal)
0.001	0.091	0.020
0.0005	(0.091)	0.040
0.0003	(0.091)	0.067
0.000001	(0.091)	20.062

*Value in parentheses are possible tolerance values where none are specified

As shown in the example, it would likely be best to select a tolerance classification that has stated tolerances rather than attempting to extrapolate the tolerance of the larger weight to those smaller as you can see that the tolerance of the larger nominal value is likely not appropriate for those smaller nominal values.

If a weight having a special nominal value that is not included is desired, the tolerance of that weight can be calculated by interpolation. For example, a nominal value that has been identified by some laboratories is a 4 lb. weight which is not shown in the tolerance table. However, we see that there is a 5 lb. and a 3 lb. nominal value with stated tolerances. Using the concept of proportionality, we can interpolate the tolerance that should be applied to the 4lb.nominal weight.

Nominal Value (lb)	Class 6 Tolerance (mg)*
5	230
4	(185)
3	140

*Value in parentheses are possible tolerance values where none are specified

The calculation for the tolerance of a 4 lb weight would be:

$$4\text{ lb } \textit{tolerance} = \frac{(230\,\text{mg} - 140\,\text{mg})}{(5\,\text{lb} - 3\,\text{lb})}(4\,lb - 3\,\text{lb}) + 140\,\text{mg}$$

with the result being 185 mg as shown in the table above.

In 1997, an attempt was made to align ASTM E617 with the 1994 version of OIML R111; this resulted in the removal of a number of different units and tolerances, leaving only those for metric nominal values. The 2013 edition of

ASTM E617 was created to provide alignment of technical specifications to those set forth in a more recent (and most current as of the publication of this article) 2004 edition of OIML R111, while at the same time bringing back the many different units and tolerances that had been removed in the 1997 edition of ASTM E617. A multitude of calculations were performed to set parameters such as material density limits so that performance criteria were met for the returning tolerances. The main criteria to be met was that a 10 % change in ambient air density would result in a mass error no greater than 25 % of the stated tolerance.

The documentary standards are written so that, regardless of the documentary standard selected, a user can properly select weight classifications with confidence to perform equally well for a NIST Handbook 44 scale verification. Since 2013, there have been several relatively insignificant edits made to ASTM E617 and, as of the date of this article, the current version of ASTM E617 is the 2018 version. ASTM documentary standards are reviewed on a five-year cycle by the responsible technical committee. So, if users of the documents have a desire to suggest changes to the standard (such as suggesting the addition of tolerances for nominal values of weights where no tolerance is currently specified) members can submit such changes to the responsible ASTM technical committee.

NIST Handbook 105-1. Handbook 105-1 (2019) recommends that NIST Class F weights ***not*** be reclassified to an ASTM or OIML accuracy classification. Reclassification would require that the artifacts be stringently evaluated to determine the actual material density; the surface finish; the magnetic susceptibility; and the permanent magnetization field. These tests are expensive and may be destructive to perform. Most calibration laboratories are not equipped to fully evaluate all parameters of the design of existing weights for reclassification. This level of testing is best left to the manufacturer to perform at the time of manufacture. Therefore, it is best if field standard weights manufactured to meet NIST HB 105-1(1990), "Class F" requirements remain identified as such and are used in applications where weights with a "Class F" designation are appropriate. Maintaining documentation of the original Class F classification will be required to ensure that these field standards are properly maintained throughout their useful life.

The earlier (1990) edition of NIST HB 105-1 will be maintained by the NIST Office of Weights and Measures (OWM). The superseded document is available for download from the NIST Research Library (**www.nist.gov/nist-research-library**) and will be provided upon request. It is expected that no new NIST Class F field standard weights will be manufactured and distributed after January 1, 2020. However, users and calibration laboratories may need information contained in the 1990 version of the handbook to reference and maintain existing Class F field standard weights for field use.

Summary. The 2019 revision of NIST Handbook 105-1 was significant, and it now applies the field standard weight designation to a number of precision weight classifications requiring special handling and historically used in a laboratory environment. A key goal of the 2019 edition is to simply provide weights and measures laboratory and field staff more tools to use in their quest to ensure the accuracy and traceability of the many varied weighing device types in commercial use. This in turn helps weights and measures officials, manufacturers, and service companies in their joint quest to create and maintain a level playing field in the U.S. weights and measures system.

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