# Making Sense of the "Min" marking on Class I and Class II Scales

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If you've been involved lately in the inspection of high-precision Class I and/or Class II scales, you've probably noticed some scale manufacturers are designating a "Min" value by marking it on the scale. This marking generally appears on the reading face of the scale. Like me, you've probably thought of the "Min" value as being the minimum acceptable load to be weighed for the scale to be suitable for its application based on its accuracy class. After all, who best to specify a minimum acceptable load than a scale's manufacturer? If, however, you delved a little deeper and considered this value in relation to the value of the verification scale division (e) and scale division (d) on scales you've inspected, you will have noticed the "Min" value can sometimes be as small as 5 (e) on scales in which (e) and (d) are different values.

The marking of such a small "Min" value in relation to a scale's verification scale division raises a lot of questions, especially considering such designation is that of the manufacturer. Some of the common questions that have been raised by inspectors and industry include:

- What is "Min" and why are some scale manufacturers marking its value on scales they produce?
- Why, in some cases, is the value designated so small (e.g., only 5 (e)?
- Can a scale be considered suitable for weighing loads this small?
- How does the "Min" value specified on a scale relate to the recommended minimum loads specified in NIST Handbook 44 (HB 44) Scales Code Table 8?

The purpose of this article is to answer these questions and provide guidance to field officials on determining the smallest acceptable load to be weighed on scales they are inspecting. First let's review some terminology associated with the values and increments displayed on a scale used in NIST Handbook 44. Those terms and their definitions are as follows:

> **scale division, value of (d). –** The value of the scale division, expressed in units of mass, is the smallest subdivision of the scale for analog indication or the difference between two consecutively indicated or printed values for digital indication or printing. (Also see "verification scale division.") [2.20, 2.22]

> **verification scale division, value of (e). –** A value, expressed in units of weight (mass) and specified by the manufacturer of a device, by which the tolerance values and the accuracy class applicable to the device are determined. The verification scale division is applied to all scales, in particular to ungraduated devices since they have no graduations. The verification scale division (e) may be different from the displayed scale division (d) for certain other devices used for weight classifying or weighing in pre-determined amounts, and certain other Class I and II scales. [2.20]

Note from the definition of "verification scale division, value of (e)" that the value of (e) is specified by the manufacturer of the device. The value of (e) is not required to be marked on a scale if it equals the value of (d) and on most scales, such a designation is not present since (e) and (d) are typically equal.

"Min" is an abbreviation used in International Recommendation OIML R 76 *Non-automatic weighing instruments* (R 76) for the term "Minimum Capacity." The term is defined in R 76 as follows:

> **Minimum capacity (Min)** Value of the load below which the weighing results may be subject to an excessive relative error.

R 76 also specifies that the value of the minimum capacity (Min) is designated to indicate that use of the instrument below this value is likely to give rise to considerable relative errors.

The criteria contained in R 76 is intended for type evaluation and not field enforcement. For this reason, there are no user requirements included in R 76. The marking of a scale's minimum capacity (Min) is a requirement of R 76. Its designation on a scale submitted by a manufacturer to OIML for certification makes possible the issuance of an OIML Certificate once all other type-evaluation criteria is met. The issuance of an OIML Certificate provides opportunity for a manufacturer to market scales internationally in the different countries that adopt OIML R 76 and require an OIML Certificate.

NIST Handbook 44 (HB 44, which has been adopted in some form by all U.S. weights and measures jurisdictions) does not require a "Min" value be marked on scales; but instead, includes a User Requirement in the Scales Code that provides recommended minimum loads based on a scale's accuracy class. OWM views the meaning of the OIML term, "Minimum capacity (Min)"and the HB 44 term,

"minimum load" to be the same. Although not required by HB 44, it is likely the "Min" marking appears on many of the commercial application scales sold in the U.S. because it is more cost effective for manufacturers to build a single scale with a common marking for both international and U.S. markets.

The parameters for scale accuracy class included in R 76 Table 3 Classification of Instruments (recreated below) are nearly identical to those in HB 44 Scales Code Table 3 Parameters for Accuracy Class. One significant difference is that R 76 does not recognize the HB 44 Class IIIL as an accuracy class, which is why it is not included in the table below. Some less significant differences are:

- R 76 limits the maximum number of scale divisions for Class IIII scales to 1 000, whereas HB 44 specifies a maximum of 1 200 divisions.
- There is an exception in R 76 Table 3 for Class I scales. The exception, found in R 76 paragraph 3.4.4., states that the minimum of 50 000 verification scale intervals does not apply to Class I scales with d < 0.1 mg. No such exception exists in HB 44.

| **Accuracy class** | **Verification scale interval, *e*** | **Number of verification scale intervals, *n* = Max/*e*** | | **Minimum capacity, Min (Lower limit)** |
|---|---|---|---|---|
| | | minimum | maximum | |
| Special (I) | 0.001 g ≤ *e** | 50 000** | – | 100 *e* |
| High (II) | 0.001 g ≤ *e* ≤ 0.05 g<br>0.1 g ≤ *e* | 100<br>5 000 | 100 000<br>100 000 | 20 *e*<br>50 *e* |
| Medium (III) | 0.1 g ≤ *e* ≤ 2 g<br>5 g ≤ *e* | 100<br>500 | 10 000<br>10 000 | 20 *e*<br>20 *e* |
| Ordinary (IIII) | 5 g ≤ *e* | 100 | 1 000 | 10 *e* |
| * It is not normally feasible to test and verify an instrument to e < 1 mg, due to the uncertainty of the test loads.<br>** See exception in 3.4.4. | | | | |

**OIML R 76 Table 3 (Classification of Instruments)**

Notice too, Table 3 of R 76 includes an additional column to the right, which provides the Minimum capacity (Min) for the different accuracy classes of scales. The values specified in this column correspond to the "recommended" minimum loads specified in HB 44 Scales Code Table 8. What makes the "Minimum capacity (Min) values" specified in R 76 Table 3 different than the "recommended minimum

load values" specified in HB 44 Scales Code Table 8 are instructions contained in OIML R 76 paragraph 3.4.3. Minimum capacity. These instructions in R 76 are to replace the verification scale interval (e) with the actual scale division (d) in the last column of Table 3 (i.e., the last column to the right). R 76 paragraph 3.4.3. is copied below.

> **3.4.3 Minimum capacity**
>
> The minimum capacity of the instrument is determined in conformity with the requirements in Table 3. However, in the last column of this Table, the verification scale interval, *e*, is replaced by the actual scale interval, *d*.

**OIML R 76 Paragraph 3.4.3 Minimum capacity**

OWM's understanding of these instructions (in paragraph 3.4.3) is that when (e) and (d) are different values on a scale (which is often the case with Class I and II scales), it is the (d) value on which scale manufacturers are to base the marking of "Min." Several photos of Class I and Class II scales recently shared with OWM by different states provide an indication that scale manufacturers are, in fact, basing the Min marking on the value of (d), rather than (e). That is, on photos of scales in which a "Min" value is marked, its value equals the product of multiplying the Min-capacity value corresponding to the scale specified in Table 3 by the scale's value of (d). That is:

(Min-capacity value in Table 3) x (scale's value of "d")

This equation accounts for why the marked Min value can be as little as 5 (e) on some scales. That is, when the value of (d) is one-tenth (e) and the Min-capacity value in Table 3 is 50 (which corresponds when the value of e ≥ 0.1 g on Class II scales), multiplying the factor "50" by the value of (d) results in a product equal to only 5 (e).

Example: Class II scale: e = 0.1 g d = 0.01g

50 x 0.01 g = 0.5 g

Such marking, unfortunately, conflicts with OWM's interpretation (and seemingly that of many U.S. weighing experts) of how the values in HB 44 Scales Code Table 8 apply to scales in which (e) and (d) are different values. That is, the opinion that recommended minimum loads are to be based on the value of (e), not (d), since both "parameters for scale accuracy class" and "applicable tolerance values" in HB

44 are based on the verification scale division (e). OWM notes it was recently concluded by the National Type Evaluation Program's (NTEP's) administrator; the NTEP Weighing Sector's technical advisor; and NTEP weighing evaluators (during the 2018 NTEP Lab Meeting); and members of the Weighing Sector (during the 2019 Weighing Sector Meeting), that the application of NIST HB 44 requirements in all cases are intended to be based on the verification scale division (e). This would include the recommended minimum load values specified in Scales Code Table 8. This conclusion aligns with a guiding principle of HB 44 that the same requirements should apply to scales used in the same application regardless of technology or design.

It is important to base a scale's minimum acceptable load on the value of (e) when considering the effects of tolerance application and digital rounding. The HB 44 maintenance tolerance applicable to Class I and Class II scales is as follows:

| Accuracy Class | Test Loads (e) | Maintenance Tolerance (HB 44) |
|---|---|---|
| Class I | 0 to 50 000 e | 1 e |
| Class II | 0 to 5 000 e | 1e |

This tolerance of 1 (e), alone, can result in a considerably large relative error when basing the minimum acceptable load on the verification scale division (e). For example, the recommended minimum load specified in Scales Code Table 8 for a Class II scale having a value of (e) equal to 0.001 g to 0.05 g is 20 (e). If this scale were used to weigh a load of 20 (e), the scale error of 1 (e) represents 5 % of the load weighed:

$$1\ e \div 20\ e = 0.05 \times 100 = 5\ \%$$

Next, consider the effect of using the same scale to weigh a load equal to 20 (d). If (d) were equal to one-tenth the value of (e) [which is normally the case for Class I and II scales with different values of (d) and (e)] an error of 1 (e) represents 50 % of a load of 20 (d):

$$1\ e \div 2\ e = 0.5 \times 100 = 50\ \%$$

*Note, the denominator of 2 (e) in these calculations is the equivalent of 20 (d) since (d) = 1/10 (e) in this example*.

This tenfold increase in relative error (i.e., from 5 % to 50 %) is solely the result of basing the minimum acceptable load on the (d) value, which in the example provided, is one-tenth the (e) value. These two examples highlight the importance of basing the minimum acceptable load on (e) when (e) and (d) are different values on a Class I or Class II scale.

The potential error caused by the rounding of digital values to the nearest minimum increment is less of a concern on Class I and II scales when (e) and (d) are different values than when they are equal, providing both (e) and (d) are read together when using the scale. This is because when (e) and (d) are different values on a Class I or II scale, the value of (e) does not round, but rather advances and declines in value only at the point when the entire range of the (d) resolution has been exceeded. Because applicable tolerances are based on (e), any rounding effect of the (d) resolution can be considered negligible when (d) is one-tenth the value of (e); which is generally, but not always the case.

It is because of the effect of tolerance application; digital rounding; and other factors which cause measurement uncertainty, that it is generally recommended most loads weighed on a scale be between one-quarter and three-quarters of scale capacity. Weighing of loads close to or equal in value to the recommended minimums specified in HB 44 Table 8 should not be the norm, but rather the occasional exception. OWM recognizes this is not always the case.

OWM is not aware of the reason(s) why a provision exists in R 76 specifying use of the actual scale division (d) to establish the minimum capacity to be marked on scales. Such marking on Class I and II scales with different values of (e) and (d) puts U.S. field officials in a very challenging position if they strive to properly enforce scale suitability by using the (e) value to determine minimum acceptable loads. R 76 is currently under revision, having last been revised in 2006. Because there is disagreement between R 76 and HB 44 with respect to the determination of the minimum acceptable load, OWM recently drafted an e-mail inquiry to the Conveners of R 76 (Germany and France) requesting an explanation of the technical justification for using (d) rather than (e) for this determination on Class I and II scales. There has been no response to date on this inquiry. Additionally, OWM discussed the concern with NTEP's Administrator, who concurred the

recommended minimum loads specified in Table 8 are intended to be based on the (e) value in all cases. OWM requested NTEP consider adding a statement to the NTEP Certificates of Conformance for those Class I and II scales in which (e) and (d) are different values, making clear the "Min" marking represents the minimum capacity value, which is an OIML marking requirement. In the U.S., recommended minimum loads are based on a scale's verification scale division (e). OWM's request is currently being considered by NTEP.

During the 2020 NCWM Interim Meeting, the Specifications and Tolerances Committee agreed to request the Chairman of the NCWM form a Task Group to review the Scales Code of NIST Handbook 44 and relevant portions of OIML R 76 and recommend changes as necessary to:

1. Clarify how error is determined in relation to the verification scale division (e) and the scale division (d);
2. Clarify which is the proper reference throughout the Scales Code:
    a. the verification scale division (e); or
    b. the scale division (d)
3. Ensure proper selection of a scale in reference to the verification scale division (e) and the scale division (d); and
4. Clarify the relationship between the verification scale division (e) and the scale division (d)

Assuming the Chairman agrees to this request, OWM expects the Min capacity issue along with other concerns related to the use of (d) and (e) to be further discussed and addressed by the NCWM Task Group.

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