What Is The Difference Between The Scale Division, d, And The Verification Scale Division, e?

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Preface

At the time this explanatory is being written, there is an item (SCL-23.3) on the agenda of the Specifications and Tolerance standing committee (S&T Committee) of the National Conference on Weights and Measures (NCWM) to amend NIST Handbook 44 on the correct implementation of scale division, d, and the verification scale division, e. This topic has been a subject of discussion within the conference for the last 3 years.

In 1984, an initiative was taken to harmonize the Scale Code in Section 2.20 of NIST Handbook 44 to the extent possible with OIML R 76 (the international standard on non-automatic weighing instruments used in legal metrology applications). Although many aspects of OIML R 76 were adopted in NIST Handbook 44, the literal language was not copied. This led to unintended deviations from OIML R 76, including the application of scale division, d, and the verification scale division, e.

In 2020, a task group was formed to identify the inconsistencies and deviations from OIML R 76 with respect to scale division, d, and the verification scale division, e. This has led to a proposal by that task group in the form of item SCL-23.3 on the NCWM S&T agenda to amend NIST Handbook 44 with the goal to bring it back in line with OIML R 76 as originally intended.

This explanatory will explain how the scale division, d, and the verification scale division, e, are globally applied in weighing instruments and to point out how the current language in NIST Handbook 44, Section 2.20, Scales, deviates from this concept. It is not the intent of NIST Office of Weights and Measures to instruct stakeholders in any way to ignore or deviate from the current regulation.

Introduction

In the scale code, there is a difference between the scale division, d, and the verification scale division, e. In 99 % of the scales that we encounter, e is the same as d. In that case, they can be interchanged in the requirements of the scale code in NIST Handbook 44; and as a result, people often use the scale division, d, to determine the tolerance. However, the tolerance must be determined by the verification scale division, e, which is defined by the manufacturer and mentioned on the name plate.

So, what if e does not equal d? How does this affect the various requirements on weighing instruments? To answer that question, we need to fully understand the difference between e and d.

Scale division, d

Let's start with d. The scale division, d, is defined 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*.

In other words, the scale division, d, is defined as the resolution of the scale. This applies to both analog scales and digital scales. And not only scales used for commercial applications, but any scale in our daily lives; the scale in the bathroom, the kitchen scale, the scale at the grocery store or the one at the post office. And it is independent of the technology used. Whether it uses a spring, counterpoise weights or an electronic load cell, the scale division, d, is the resolution of the indication.

But what if the scale does not have an indication (no display, no printout)? For example, an equal-arm balance with an unknown load on one side and weights of known value on the other side. The scale is balanced when the load on each side is equal. The only indication there is, is a needle that is lined up with a mark when the scale is in balance.

This balance is a perfectly good instrument to accurately determine the weight of a load without having an indication. A balance is a scale but does not have an indication and therefore no scale division, d.

Verification scale division, e

Now the verification scale division, e. The definition for verification scale division, e, states:

> **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, is a measure for the accuracy of the scale. It is specified by the manufacturer and defines the accuracy class of and the tolerance applied to the device. Please note that the definition does not say anything about the indication of the scale. As a matter of fact, it states that it applies to all scales. This includes the balance from the example in the previous paragraph. Every (legal for trade) scale has a verification scale division, e, but not always a scale division, d.

Relationship between e and d

Although e and d are two completely different characteristics of the scale (e is a measure for the accuracy while d is the resolution of the indication), it does not mean that there is no relationship between these values. For most scales in commercial applications, especially class III and class IIII scales, the scale division, d, must be the same as the verification scale division, e, and there is a good reason for this requirement.

If the resolution of the scale is higher than the verification scale division, this may create a false sense of accuracy with the user (or customer). For example, a scale has a verification scale division of 1 kg then the tolerance of the scale would be 1 kg for loads up to 500 kg. If the indication shows "123.77 kg" then the user could interpret this as the scale being accurate in the order of 0.01 kg (10 g). Why else would the scale show these extra digits? To avoid this false sense of accuracy, the scale division cannot be smaller than the verification scale division, (with the exception of some class I and II scales).

But, except for weight classifiers, the scale division can also not be larger than the verification scale division because that would create another problem. If the scale division is larger then, the relative error due to the scale resolution would increase. This especially plays a large role at small loads. The uncertainty on a digital scale due to its resolution is ½ d. If the indication shows "123 kg" then the actual value (apart from the accuracy of the measurement) lays somewhere between 122.50 kg and 123.49 kg. But because the display does not have enough digits, it rounds it off to 123 kg. For a class III digital scale (where d=e) the minimum recommended load equals 20 d. That means that the uncertainty due to the resolution is 0.5 d/20 d = 2.5%. This is deemed an acceptable uncertainty for a class III scale.

Now let's imagine a scale with a scale division ten times larger than the verification scale division, d=10 e. In order to reach the same 2.5% uncertainty, the minimum recommended load would be 20 d which equals to 200 e. On a class III scale, the tolerance changes over at 500 e. Normally in that segment the scale has 500 e-20 e (20 d) = 480 e to operate above the minimum load. But with d=10 e, this segment has been reduced to only 300 e. In other words, when d is larger than e the uncertainty due to the display resolution becomes exceptionally large. The exception to this is a weight classifier where d is larger than e because of the way these scales round up to the next scale division.

So, the conclusion is that for most applications it is desired that the scale division, d, equals the verification scale division, e. Only in special applications (e.g., laboratory or pharmaceutical applications) is it useful to have an additional digit available. But in those cases, it is expected that the operator is trained to understand the relationship between the displayed resolution and the actual accuracy of the scale. Where d<e the extra digit must be clearly differentiated from the remaining digits to avoid confusion. Only class I and class II scales are allowed to have auxiliary digits.

Accuracy class

The accuracy class of the scale is based on the number of verification scale divisions. In general, (with some exceptions), the number of verification scale divisions, e, per accuracy class are as follows:

Accuracy class	Number of verification scale divisions, e
I	50,000 and up
II	5000 – 100,000
III	500 – 10,000
III L	2000 – 10,000
IIII	100 - 1200

Table 1: Simplified table of scale accuracy classes

Note: The parameters for accuracy classes table (table 3) in Section 2.20 of the current version of NIST Handbook 44 lists the "number of scale divisions" per accuracy class. This is deceiving since "number of scale divisions" is actually defined in appendix D as the scale capacity divided by e, or in other words: the number of <u>verification</u> scale divisions. Item SCL-23.3 on the NCWM S&T

agenda aims to correct this and other inconsistencies regarding the use of the terms "scale division" and "verification scale division".

The accuracy class is determined by the accuracy of the scale, not the resolution of the indication. If the resolution of the scale is increased, that doesn't mean that the scale is more accurate. The accuracy of a scale is expressed by the verification scale division, e. Therefore, the accuracy class is determined by e and not d.

Tolerance

Like the accuracy class, the tolerance is also based on the verification scale division, e. The manufacturer specifies how accurate the scale is. The accuracy is not based on the displayed resolution. Simply said: a scale doesn't get more accurate if it displays more digits. As a matter of fact, the scale retains the same accuracy if you remove its display entirely as we have seen in the example of a balance.

The tolerance of a scale also depends on the accuracy class as shown in the table below.

	Maintenance Tolerance			
Accuracy class	1 e	2 e	3 e	5 e
I	0 e ≤ m ≤ 50,000 e	50,000 e < m ≤ 200,000 e	200,000 e < m	
II	0 e ≤ m ≤ 5,000 e	5,000 e < m ≤ 20,000 e	20,000 e < m	
III	0 e ≤ m ≤ 500 e	500 e < m ≤ 2,000 e	2,000 e < m ≤ 4,000 e	4,000 e < m
IIII	0 e ≤ m ≤ 50 e	50 e < m ≤ 200 e	200 e < m ≤ 400 e	400 e < m
III L	0 e ≤ m ≤ 500 e	500 e < m ≤ 1,000 e	Add 1 e for every 500 e increments of m	

Table 2: Tolerance based on the accuracy class and the load, m, on the scale

Note: *The tolerance table (table 6) in Section 2.20 of the current version of NIST Handbook 44 states that the tolerance and loads are expressed in scale divisions. This deviates from what is globally applied. Item SCL-23.3 on the NCWM S&T agenda aims to correct this and other inconsistencies regarding the use of the terms "scale division" and "verification scale division".*

Application of e and d in the requirements on weighing instruments

As mentioned, several times before, the tolerance is based on and expressed in the verification scale division, e, regardless of the displayed resolution. Therefore, every requirement that has a tolerance defined, is based on the verification scale division, e. There are some requirements that are based on the scale division, d, but those requirements do not define a tolerance.

Note: *Section 2.20 of the current version of NIST Handbook 44 contains several inconsistencies regarding the use of the terms "scale division" and "verification scale division". Item SCL-23.3 on the NCWM S&T agenda aims to correct these inconsistencies and to bring this section of the NIST Handbook in line with the interpretation as explained in this explanatory.*

For example, the discrimination test is performed to check the sensitivity of the scale indication. Basically, the addition of a small load should result in a change in the indication. This change is related to the resolution of the indication and therefore the test is performed with respect to d. It is acceptable to relate this test to the scale division, d, instead of the verification scale interval, e, because the required change in the indication is not a tolerance on the accuracy of the scale.

Another requirement where there is confusion about the use of e versus d is the range of the "center-of-zero" indicator. The maximum starting error at zero balance before the weighment is 0.25 e (this is deemed to be acceptable for an accurate weighment). Since this is a tolerance, it is expressed in verification scale divisions, e. This maximum allowed error in the final weighing result, due to the offset of the zero, does not depend on the displayed resolution. Therefore, scales with a digital indication must have a "center-of-zero" indicator to show the user that the zero error is within 0.25 e instead on 0.25 d. Instruments with a higher resolution ($d < e$) don't need such indicator because when the display shows 0 d, the error is automatically within 0.25 e.

Note: In specification S.1.1.1 in Section 2.20 of the current version of NIST Handbook 44, the operating range of the "center-of-zero" indicator is expressed in scale divisions. This deviates from what is globally applied. Item SCL-23.3 on the NCWM S&T agenda aims to correct this and other inconsistencies regarding the use of the terms "scale division" and "verification scale division".

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