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Agreement of Indications on Shift or Section Tests
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WMD frequently receives inquiries concerning the correct application of NIST Handbook 44 Scales Code, paragraph T.N.4.4. Agreement of Indications on Shift or Section Tests. The purpose of this article is to explain the intent of the paragraph and define its correct method of application.

History and Purpose of T.N.4.4.
Scales Code paragraph T.N.4.4. Shift or Section Tests was fashioned from Scales Code paragraph T.1.8. Sectional Tests on Vehicle, Livestock, and Railroad Track Scales, which first appeared in Handbook 44 in 1977. Paragraph T.1.8. applied only to the results of section tests on vehicle, livestock, and railroad scales and was intended to limit the amount of error on scales having two-way traffic patterns. It addressed a primary concern that a weighing error of 0.4 % could result from weighing loaded vehicles in one direction and unloaded vehicles in the opposite direction on the same scale. In 1977 the maintenance tolerance applicable to these scales was ± 0.2 % of applied load; a 0.4 % weighing error could result if one end of a scale had a + 0.2 % error and the opposite end had a - 0.2 % error. Paragraph T.1.8. required the range of the results of the section test to agree to within the absolute value of the maintenance tolerance applicable to the applied test load.

T.1.8. Sectional Tests on Vehicle, Livestock, and Railroad Track Scales.- The maximum deviation between indicated values on test load applied to individual sections shall not be greater than

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Scales Code Paragraph T.1.8.
(This Paragraph No Longer Exists in Handbook 44)

Paragraph T.1.8. was removed from Handbook 44 in 1985 and replaced with Paragraph T.N.4.4. However, because paragraph T.N.4.4. was part of the New Scales Format and Tolerances appearing in the 1985 version of the Handbook, it did not become enforceable until January 1, 1986. Paragraph T.N.4.4. expanded the provisions of T.1.8. to include, not only results of section tests on vehicle, axle-load and livestock scales, but also the results of shift tests, thus broadening the application of the requirement to other scale types. However, unmarked scales with less than 2000 scale divisions or more than 5000 scale divisions were exempt from having to comply. Consequently, the 1986 Handbook 44 version of paragraph T.N.4.4. applied to the results of section tests on all vehicle, axle-load, and livestock scales, as well as the results of shift tests on all marked scales, and those remaining unmarked scales with more than 2000 total divisions or less than 5000 total divisions.

In 1987, the Specifications and Tolerances (S&T) Committee of the 72nd National Conference on Weights and Measures (NCWM) received a request to amend paragraph

T.N.4.4. by limiting the application of the requirement to multiple-section scales. The NCWM voted to limit the application of the requirement to unmarked multiple-section scales and all marked scales, noting in the final report for that year that the test was a good one and should be maintained for marked scales. The S&T Committee indicated that one purpose of the requirement was to prevent a scale from having shift test errors at the extreme limits of tolerance. The tolerance on the range of shift test errors would allow scale accuracy to deteriorate somewhat without the scale going out of tolerance. In justifying why an exemption was granted for certain types of unmarked scales, the S&T Committee explained that it did not intend for the requirement to apply to unmarked bench, floor, and counter scales but believed it was an appropriate requirement for marked scales since these devices were manufactured and installed after the effective date of the new code. Paragraph T.N.4.4. as shown below has remained unchanged since 1988.

T.N.4.4. Shift or Section Tests. The range of the results obtained during the conduct of a shift test or a section test shall not exceed the absolute value of the maintenance tolerance applicable and each test result shall be within applicable tolerances.
(Added 1986)

Scales Code Paragraph T.N.4.4.

Two Separate Tolerance Applications
It is important to recognize that two separate applications of tolerance are specified by paragraph T.N.4.4. Under the provisions of this paragraph, a tolerance is to be applied to the range of results obtained during a shift or section test and to each individual shift or section test result. For this reason, the tolerance value applicable to the range of results may be different from the tolerance value applicable to each individual result. The reason these tolerance values may differ is because the absolute value of maintenance tolerance is always applied to the range of shift or section test results, whereas applicable tolerance (i.e., maintenance or acceptance, whichever is being applied based upon Handbook 44, G-T.1. and G-T.2.) is applied to each individual shift or section test result. For example, acceptance tolerance would apply to the individual shift test results obtained from a scale that is being officially tested for the first time within 30 days of being placed into service. However, the absolute value of maintenance tolerance would apply to the range of the individual shift test results obtained from that scale.

Determining the Range of Results
The range of a set of numbers is the difference between the lowest and highest number displayed in the set. Determining the range of a set of numbers is a simple matter of subtracting the lowest number from the highest number. For example, given the following set of numbers: (+10, 0, 0, -10, -10, -10, and -20), -20 is the lowest and +10 is the highest. Therefore, to determine the range of this set of numbers, subtract -20 (the lowest number) from +10 (the highest number). The equation for determining the range of these two numbers is easily set up as follows:

$$Range = 10 - (-20)$$

Because subtracting a number is the same as adding its opposite, this equation may be restated in simpler form:

$$\text{Range} = 10 + 20 = 30$$

Thus, the range of the example set of numbers shown in parenthesis above is 30.

A real number line is useful in providing a visual display of range. Notice in Figure 1. that there are two points marked on the number line; one of which is the highest number in the example set of numbers provided above; and the other, the lowest number. The total distance between these two points, i.e., 30 intervals, equals the range.
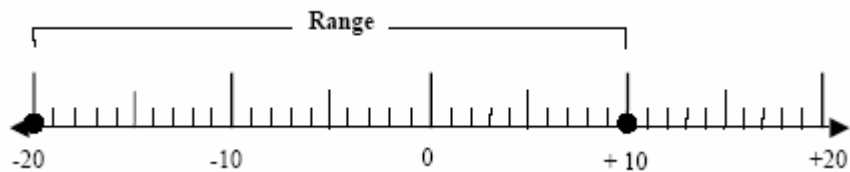

Figure 1. Range Displayed on a Number Line

Comparing Individual Shift or Section Test Results to Applicable Tolerances
To determine whether or not the individual results of the shift or section test comply with the provisions of T.N.4.4., each individual shift or section test result must be compared to applicable tolerance. To be compliant, no individual shift or section test result may exceed that tolerance. Applicable tolerance, as referenced by paragraph T.N.4.4., is the tolerance that is applied to a scale based upon the provision of GT.1. Acceptance Tolerances and GT.2. Maintenance Tolerances. For example, Table 1 depicts the results of a section test on a vehicle scale equipped with a 10 lb division. If the results shown in Table 1 had been obtained from a scale that had been in service for more than 30 days, maintenance tolerance would be the applicable tolerance.

Load Position	Test Load Pounds	Scale Indication Pounds	Error Pounds	Within Maintenance Tolerance?	Range of Results
Section 1	25000	25 010	+ 10	Yes	
Midpoint	25 000	25 000	0	Yes	
Section 2	25 000	25 000	0	Yes	
Midpoint	25 000	24 990	- 10	Yes	40 lb
Section 3	25 000	24 990	- 10	Yes	
Midpoint	25 000	24 90	- 20	Yes	
Section 4	25 000	24 980	-30	Yes	

Table 1 Example of Section Test Results : d = 10 lb

To determine whether the individual section test results shown in Table 1 comply with T.N.4.4., each result must be compared to applicable tolerance. The Handbook 44 maintenance tolerance applicable to all vehicle scales, whether marked or unmarked, is

one (1) division of allowable error for each 500 divisions of test load. Acceptance tolerance is one-half the maintenance tolerance values. Assuming the results shown in Table 1 were obtained from a scale that had been in service for more than 30 days and the minimum division size is 10 lb, the tolerance applicable to the 25 000 lb section test load would be ± 50 lb (i.e., maintenance tolerance, which is equal to one (1) division of error (10 lb) for each 500 divisions (5 000 lb) of test load). The acceptance tolerance applicable to this same test load would be ± 25 lb (i.e., one-half maintenance tolerance values).

From the results recorded in the shaded area of Table 1, it can be seen that no individual section test error exceeds the value of maintenance tolerance. It can therefore be concluded that the individual section test results are compliant with this particular provision of T.N.4.4. This would not be the case, however, if acceptance tolerances were being applied. If acceptance tolerances were being applied, no individual section result could exceed ± 25 lb (i.e., one-half maintenance tolerance values) and since the individual section result recorded for Section 4 is in excess of -25 lb, the scale would fail to conform.

Comparing the Range of Results to the Absolute Value of Maintenance Tolerance
To determine whether or not the range of results obtained during a shift or section test comply with the provisions of paragraph T.N.4.4., the range of the results must first be determined and then compared to the absolute value of the maintenance tolerance applicable to the test load.

Note: The absolute value of a tolerance is the value of that tolerance without considering the positive or negative sign. For example, whereas the maintenance tolerance applicable to a 25 000 lb test load applied to a vehicle scale with a 10 lb division size is ± 50 lb, the absolute value of that maintenance tolerance is 50 lb (that is, the number without the positive or negative sign). To help explain the intent of how paragraph T.N.4.4. is to be applied, Handbook 44 provides the following definition for the term absolute value.

> **absolute value.** The absolute value of a number is the magnitude of that number without considering the positive or negative sign.[2.20]

The range of the individual section test results shown in Table 1 is determined by subtracting the lowest value (i.e., -30 lb) from the highest value (i.e., +10 lb) in the set. Using the same formula as described under 'Determining the Range of Results,' the range of the errors indicated in Table 1 is determined as follows:

$$\text{Range} = 10 - (-30)$$

When restated in simpler form, the equation becomes:

$$\text{Range} = 10 + 30 = 40$$

Because the range of the results of the section test is 40 lb and the absolute value of maintenance tolerance is 50 lb, the performance of the scale complies with this particular provision of T.N.4.4.

Summary of Results
The following summarizes how the provisions of paragraph T.N.4.4. are to be correctly applied to the results shown in Table 1:

1. If maintenance tolerances were being applied to the scale:
   a. each individual section test result complies with applicable maintenance tolerances, and
   b. the range of the results obtained during the section test are within the absolute value of the maintenance tolerance applicable to the test load.

Conclusion: Section test results comply with both provisions of T.N.4.4.

2. If **acceptance** tolerances were being applied to the scale:
   a. each individual section test result does not comply with applicable acceptance tolerance, however,
   b. the range of the results obtained during the shift test are within the absolute value of the maintenance tolerance applicable to the test load.

Conclusion: Section test results fail to comply with the provisions of T.N.4.4. because one individual section result exceeds applicable tolerance.

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