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Determination of Test Loads & Tolerances for Multi-interval and Multiple Range Weighing Instruments

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In a February 2004 *W&M Quarterly* newsletter article, WMD discussed the differences between multi-interval and multiple range weighing instruments (scales) and identified technically correct test procedures for these devices. This article discusses the procedures used in correctly determining and applying tolerances in NIST Handbook 44 Scales Code paragraphs T.1. Tolerance Values (for unmarked scales), T.N.3.1. Maintenance Tolerances, T.N.3.2. Acceptance Tolerances, and T.N.4.4. Shift or Section Tests as they apply to multi-interval and multiple range weighing instruments. Also, this article addresses the differences in conducting decreasing-load tests between ***marked and unmarked*** automatic indicating scales and the correct application of tolerances when shift tests are conducted at test loads where the range of results are in different intervals. The reader should also review the February 2004 article titled "Tests for Multi-interval and Multiple Range Weighing Instruments" which can be found on the WMD website in the *W&M Quarterly* Archives (http://ts.nist.gov/WeightsAndMeasures/upload/A-005.pdf) for additional background information on the differences between the two types of instruments and to identify technically correct test procedures for these devices.

The following steps demonstrate the determination and application of tolerances of a Class III multi-interval or multiple range instrument. The same procedure applies for Class I, II, III L, and IIII scales as well as all unmarked scales of this type. Note that in scales where the scale division (d) is different than the verification division (e), (e) is to be used in the application of tolerances along with the number of scale divisions (n).

Step I. Determine the number of scale divisions in each weighing segment (WS) or weighing range (WR). In order to determine that number of scale divisions (n) for each WS or WR, treat each WS or WR as if it were a separate scale. That is, assume each WS or WR starts at zero):

WS or WR (lb)	Value of Scale Div (lb/d)	No. of Scale Div (n)*
0 - 5	0.005	1000
5 - 20	0.01	2000
20 -30	0.02	1500
30 – 50	0.05	1000

* (n) = (Cap in lb) ÷ (lb/d)
(n) = (50 lb ÷ 0.05 lb) = 1000

For ***unmarked*** scales, use the largest value for (n) to determine the number of scale divisions and determine whether or not the tolerances for marked scales would apply. In the above example, the maximum number of scale divisions in the WS or WR is 2000.

For ***unmarked*** scales, tolerances are found in Table T.1.1. Tolerances for Unmarked Scales. According to Table 1.1. for "All other scales," the tolerances are found in Table 6 if the number of scale divisions falls between 2000 and 5000. However, maintenance tolerances for "All other scales" with (n) greater than 5000 (e.g., 70 lb x 0.01 lb) are 0.1 % of the test load.

Step II. Review the List of Class III Tolerances:

Test Load	Maint. Tolerance
0- 500	1
501- 2 000	2
2001- 4 000	3
4001-10 000	5

Step III. Determine tolerances at the tolerance breakpoints up to the maximum capacity of each WS or WR:

Test Load (d)	Test Load (lb)	Maint. Tol. (d)	Maint. Tol. (lb)
WS or WR 1: **0-5 lb x 0.005 lb**			
500	2.5	1	0.005
1000	5	2	0.01
WS or WR 2: **5-20 lb x 0.01 lb**			
~~500~~	~~5.0~~	~~1~~	~~0.01~~
2000	20	2	0.02
WS or WR 3: **20-30 lb x 0.02 lb**			
~~500~~	~~10~~	~~1~~	~~0.02~~
1500	30	2	0.04
WS or WR 4: **30-50 lb x 0.05 lb**			
~~500~~	~~25~~	~~1~~	~~0.05~~
1000	50	2	0.1
Note: The rows that are **shaded** indicate test loads that are located in a lower WR or WS and do not need to be repeated.			

Step IV. Determine the final set of tolerances for the scale by first eliminating the test loads in each WS or WR that would be included in the testing of the previous WS or WR and then listing the remaining test loads and tolerances:

Test Load		Maint. Tol.		Accept. Tol.	
lb	d	lb	d	lb	d
0-2.5	0-500	0.005	1	0.0025	*0.5
2.505-5	501-1000	0.01	2	0.005	1
5.01-20	5001-2000	0.02	2	0.01	1
20.02-30	1001-1500	0.04	2	0.02	1
30.05-50	601-1000	0.1	2	0.05	1

*See *W&M Quarterly* Archives article "Applying One-half "d" Tolerances" (http://ts.nist.gov/WeightsAndMeasures/upload/A-003.pdf)

The application of ***decreasing-load test*** tolerances are different for multiple range instruments since the scale interval for decreasing load does not automatically change from the higher value to the lower value when the load decreases from the higher to the lower WR. That is, the tolerance is based on the scale interval of the WR for the largest test load even if the one-half capacity test load is in a lower WR. The following tables represent the difference in the application of decreasing-load test tolerances between multiple range and multi-interval scales.

Decreasing-load Test and Zero Return Tolerances for Multiple Range Instruments						
Test Load		**Maint. Tol.**		**Accept. Tol.**		**WR**
lb	d	lb	d	lb	d	
50	1000	0.1	2	0.05	1	4
25[1]	500	0.05	1	0.025	0.5	4
15	300	0.05	1	0.025	0.5	4
10	100	0.05	1	0.025	0.5	4
5	50	0.05	1	0.025	0.5	4
0	0	0.05	0.5	0.025	0.5	4

[1] Minimum Decreasing-load Test (N.1.2.1. Scales Marked I, II, III, or IIII. and N.1.2.2. All other Scales)

Decreasing-load Test and Zero Return Tolerances for Multi-interval Instruments						
Test Load		**Maint. Tol.**		**Accept. Tol.**		**WS**
lb	d	lb	d	lb	d	
50	1000	0.1	2	0.05	1	4
25[2]	1250	0.04	2	0.025	1	3
20[1]	2000	0.02	2	0.01	1	2
15	1500	0.02	2	0.01	1	2
5[1]	500	0.005	1	0.025	0.5	1
0	0	0.005	1	0.025	0.5	1

[1] Minimum Decreasing-load Test (N.1.2.1.)

[2] Minimum Decreasing-load Test (N.1.2.2.)

WMD has received questions during training sessions about the correct tolerance application when a test load is at or close to a point at which the scale interval changes on multi-interval and multiple range scales and the results are in two different sized intervals. Field officials have reported that this frequently occurs while conduct ing the shift test at half capacity since one-half scale capacity is also where the WS or WR changes. Scales Code paragraph T.N.4.4. requires that the range of results obtained while conducting the shift or section test shall not exceed the absolute value of the maintenance tolerance for scales marked with an **accuracy** class (including unmarked heavy capacity scales listed in Table 1.1.). That is, the largest difference between test results from any two shift or section test positions can not exceed the value of the applicable maintenance tolerance.

Normally, on a 30 lb x 0.01 lb single range bench or counter scale, the shift test is conducted according to paragraph N.1.3.1. Shift Test. with a test load of 15 lb (1/2 capacity), and a maintenance tolerance of 2 d (0.02 lb) applies. If the results of the shift test are 1 d, -2 d, 0 d, and +1 d, all the individual results are within maintenance tolerance according to Table 6. In order to verify compliance with T.N.4.4., simply take the difference between the sections with the largest errors.

$$[(+1\ d) - (-2\ d)] = 3\ d$$

The ***absolute value*** of the maintenance tolerance for 15.00 lb is 2 d (not ± 2 d); therefore, the scale in the above example fails T.N.4.4.

Consider the test of a Class III multiple range or multi-interval scale with the following parameters:

0 to 15 lb x 0.005 lb (n = 3000)
15 to 30 lb x 0.01 lb (n = 3000)

How do you determine the T.N.4.4. tolerance when the shift test results are in two different intervals because they are in two different WR or WS? In an example where a one-half capacity "test load" equals 15 lb and 15 lb is in the lower WS or WR (n = 3000), the following is a sample of shift test results that helps demonstrate the problem:

Pos.	**Ind. (lb)**	**Error (lb)**	**Error (d)**
Front	14.990	-0.010	-2 lower WS or WR
Left	14.995	-0.005	-1 lower WS or WR
Back	15.01	+0.01	+1 upper WS or WR
Right	15.000*	0.000	0 lower WS or WR
Note: The 15 lb test load in this example is in the lower range where d = 0.005 lb.			

All individual indications are within maintenance tolerances. Do these results comply with T.N.4.4.? The question arises when the results are reported in intervals with different values. *Remember that a tolerance is defined in Handbook 44 Appendix D as an allowable error or departure from a true performance or value (test weight or test load)!*

WMD recommends determining the range of results by taking the largest difference between any two positions using the actual weight indications and then converting the result to the value of d as follows:

Range of Results

15.01	lb (higher WS or WR)
-14.990	lb (lower WS or WR)
0.020	**lb ÷ 0.005 lb/d = 4 d**

As you can see, the result of the calculation expressed in d exceeds the tolerance for the 15 lb test load and the scale fails to comply with the tolerance requirement in T.N.4.4

when d = 0.005 lb. However, some scales may change from the lower to the higher WS or WR at 14.995 lb. Therefore, the 15 lb test load will be in the higher WR or WS. As a result, the scale in the above example would pass using a 15 lb test load (n = 1500) where d = 0.01 lb as follows:

Range of Results

15.01	lb (higher WS or WR)
-14.990	lb (lower WS or WR)
0.020	**lb ÷ 0.01 lb/d = 2 d**

Even though compliance with T.N.4.4. varies for multi-interval and multiple range scales, the application of the tolerances is consistent with the philosophy used for the step tolerances where the value of d relates to the accuracy of the scale.

In general, the determination of test loads and tolerances for multi-interval and multiple range scales follows the same basic principles as single range scales. The reader must be aware of the differences between these scales and single range scales in order to determine the correct test loads and tolerance. For multi-interval and multiple range scales, test loads are based on the number of scale divisions from zero to the capacity of each WS or WR (note that "decreasing-load" test loads are different for marked and unmarked scales). Tolerances are based on the test load using the interval of the applicable WS or WR, not the interval of the indicated result. That is, the tolerances in Scales Code Table 6 are based on the number of divisions of the test load. The exception to using Table 6 is for some classes of unmarked scales in Table 1.1. (e.g., "all other scales" where n > 5000). For additional information on testing multi-interval or multiple range scales, contact Steve Cook by telephone at (301) 975-4003 or by e-mail at stevenc@nist.gov.