Substitution and Strain-Load Methods of Testing Scales

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RESOURCES

Wis. Statute Ch. 98
http://docs.legis.wisconsin.gov/statutes/statutes/98/Title

Wis. Admin. Code ATCP 92
https://docs.legis.wisconsin.gov/code/admin_code/atcp/090/92/Title

NIST Handbook 44
https://www.nist.gov/publications/nist-handbook-44-specifications-tolerances-and-other-technical-requirements-weighing

"Substitution" or "strain-load" tests are methods used for testing scales when the amount of available test weights is less than the minimum test load required by NIST Handbook 44 2.20. Table 4 for the capacity of the scale. The minimum test weight requirement from Table 4 must always be met.

When using these methods, care must be taken each time weights are added or removed to avoid disturbing the scale mechanism in any way that would affect the balance condition. Similar care must likewise be used in establishing and duplicating the balance condition on which the substitution depends for its accuracy. Some error is inevitable at each substitution, but unless this error is held to a minimum, the accumulated error after several substitutions may reach serious proportions.

Substitution Method

The substitution method uses a **known test weight**, which is applied to the scale and then error weights are added until the scale indicator is brought to a readily reproducible balance condition. For example, the exact coincidence between the indicator and some graduation on a dial scale. A weigh beam that just fails to "bump" when released on a beam scale. Finding the edge of the zone of uncertainty on a digital scale which is indicated by the weight display flickering back and forth between two consecutive divisions. Once that balance condition is reached, the known weight is then carefully removed and substituted with material (e.g. sand, grain, scrap metal) that is available to bring the scale back into the reproducible balance condition. All error weights applied previously are now removed. With the material remaining on the scale, the known test weight is placed back on the scale. Tolerances are applied to the entire amount of load of test weights and substitution material represented on the scale. From this point the process may be repeated (leaving the substitution material on the scale) if necessary.

No more than three substitutions may be used during substitution testing, after which the tolerances for strain load tests must be applied to each set of tests.

Errors: The entire load on the load-receiving element of the scale at the time of making any test observation including the substitution load is regarded as a **known load**, and any observed error is an error on the total load on the scale just as if the entire load was comprised of test weights. For example, if 1,000 lbs. of test weights were available and three substitutions were conducted, the total load on the scale would be 4,000 lbs. and the tolerance for a 4,000 lb. load would be applied.

Strain-Load Method

The strain-load method applies an **unknown load** to the load-receiving element of a scale to establish a reference load, to which test weights are then added. This method is commonly used to determine the accuracy of a higher portion of the total weighing range of a scale.

To conduct the test on a scale with a digital indicator, ten 1/10 scale division field test weights (error weights) are applied to the scale and the scale is re-zeroed. An unknown load such as equipment or a loaded hopper is applied to the scale. The unknown load is then balanced out on the scale by first removing error weights until the edge of the lower zone of uncertainty is found (again, as indicated by the reading flickering between two consecutive divisions). The error weights that were removed are placed back on the scale in a separate location from the other error weights. Then error weights are added to the second group of error weight until the edge of the upper zone of uncertainty is found. Remove half of the error weights in the second group. The indicator should now be centered within the displayed division.

The test weights are then added to the scale. The tolerances are applied only to the amount of known test weight added. For example, if 5,237 lbs. of strain load is applied and then 1,000 lbs. of test weights are applied, the total load on the scale would be 6,237 lbs. and the tolerance for the 1,000 lb. load of test weights would be applied. Not the tolerance for 6,237 lbs.

Errors: In the strain-load method, observed errors are errors on the test-weight load only, since before each application of the test-weight load the strain load of unknown value has been balanced out; accordingly, the tolerances to be applied are to be selected according to the value of the test-weight load in each instance of an accuracy observation under the strain-load method.

This application of tolerances to only the known test weight placed on the scale is the basic difference between "strain-load" testing and the "substitution" method. The "strain-load" method is dependent on the addition of unknown weight only to stress, or load up the scale to the working range of the scale. In the "substitution" method, the substitution material is added in an amount equaling the known test load and thereby becomes a known amount.

Minimum test loads required under Table 4 of the Scales Code in NIST Handbook 44:

Table 4.
Minimum Test Weights and Test Loads[1]

Devices in Metric Units				Devices in U.S. Customary Units		
Device Capacity (kg)	Minimums (in terms of device capacity)			Device Capacity (lb)	Minimums (in terms of device capacity)	
	Test Weights (greater of)	Test Loads[2]			Test Weights (greater of)	Test Loads[2]
0 to 150 kg	100 %			0 to 300 lb	100 %	
151 to 1 500 kg	25 % or 150 kg	75 %		301 to 3 000 lb	25 % or 300 lb	75 %
1 501 to 20 000 kg	12.5 % or 500 kg	50 %		3001 to 40 000 lb	12.5 % or 1 000 lb	50 %
20 001 kg+	12.5 % or 5 000 kg	25 %[3]		40 001 lb+	12.5 % or 10 000 lb	25 %[3]

Where practicable:

- Test weights to dial face capacity, 1000 d, or test load to used capacity, if greater than minimums specified.
- During initial verification, a scale should be tested to capacity.

[1] If the amount of test weight in Table 4 combined with the load on the scale would result in an unsafe condition, then the appropriate load will be determined by the official with statutory authority.

[2] The term "test load" means the sum of the combination of field standard test weights and any other applied load used in the conduct of a test using substitution test methods. Not more than three substitutions shall be used during substitution testing, after which the tolerances for strain load tests shall be applied to each set of test loads.

[3] The scale shall be tested from zero to at least 12.5 % of scale capacity using known test weights and then to at least 25 % of scale capacity using either a substitution or strain load test that utilizes known test weights of at least 12.5 % of scale capacity. Whenever practical, a strain load test should be conducted to the used capacity of the scale. When a strain load test is conducted, the tolerances apply only to the test weights or substitution test loads.
(Amended 1988, 1989, 1994, and 2003)

Note: GIPSA requires devices subject to their inspection to be tested to at least "used capacity," which is calculated based on the platform area of the scale and a weight factor assigned to the species of animal weighed on the scale. "Used capacity" is calculated using the formula: Used Scale Capacity = Scale Platform Area x Species Weight Factor

Where species weight factor = 540 kg/m^2 (110 lb/ft^2) for cattle, 340 kg/m^2 (70 lb/ft^2) for calves and hogs, and 240 kg/m^2 (50 lb/ft^2) for sheep and lambs.