Chapter 4

Pretest Determinations

Objectives

In this chapter you will learn how to determine the specific tolerances to apply to a scale to be tested. You will study tolerance structure for vehicle and axle-load scales and learn how to apply the tolerances to specific scales. After studying this chapter, you should be able to:

1. Complete a tolerance worksheet for a vehicle or axle-load scale.

2. Determine the maximum test load to be applied during the test.

3. Apply tolerances for tests to be conducted in the Test portion of the field examination. These are:

   - decreasing-load test
   - increasing-load test
   - repeatability
   - shift test
   - substitution test
   - strain-load test
   - zero-load balance change

4. Explain the meaning of the following terms:

   acceptance tolerance
   decreasing-load test
   discrimination (of an automatic-indicating scale)
   increasing-load test
   maintenance tolerance
   sensitivity requirement (SR)
   repeatability
   shift test
   strain-load test
   substitution test
   tolerance

   These terms are printed in **bold type** when first introduced. Complete definitions are listed alphabetically in Appendix A.

General Considerations

A major part of an official field examination is the test of the device with field standard test weights to determine its performance in use.

A scale that would always weigh without error would be ideal. However, since perfection cannot be attained, regulations are established that set a limit on the amount of error that will be allowed. These allowances for error are called **tolerances**. Tolerances fix the legal limits of inaccuracy for a weighing or measuring device.

tolerance. - A value fixing the limit of allowable error or departure from true performance or value.

NIST Handbook 44, Appendix D, Definition of "Tolerance"

The tolerances that are established are based on several criteria, the most important of which are:

- The tolerances should not be so large that an allowable error would cause financial harm to either the buyer or the seller in a transaction.

- The tolerances should not be so small that the cost of manufacturing and maintaining the scale is unreasonable. Note that these costs are usually passed on to the final purchasers of finished commodities.

Scale errors are expressed in terms of the difference between the indicated (and/or recorded) weight and the actual weight of the load on the scale. Scale errors are expressed in terms of registration: that is, the actual weight is subtracted from the indicated weight to determine the error value. Depending upon whether the difference is a positive or negative value, errors are designated as either **overregistration** or **underregistration**.

Overregistration means that the weight value indicated by the scale is more than the real weight. With a 5000-pound test weight on the scale platform, a display of 5020 lb is an example of overregistration. The error is +20 lb.

Underregistration means that the weight value indicated is less than the real weight. With a 5000-pound test weight on the scale platform, a display of only 4980 lb is an example of underregistration. The error is -20 lb.

According to Handbook 44, all tolerances for scales apply equally to overregistration and to underregistration. For example, if the applicable tolerance value for a given test is 20 lb and the test load is 20,000 lb, any indication between 19,980 (actual weight minus the tolerance value) and 20,020 (actual weight plus the tolerance value) would be considered to be within the tolerance requirement for that test.

The tolerances that are established in Handbook 44 are primarily for use by weights and measures officials. As explained in Chapter 3, they are not to be used by the owner of the device or a serviceperson either to adjust a scale so that its registration benefits the owner or to compensate for equipment that is in need of service or replacement. Scales and other weighing and measuring devices are to be adjusted as close to zero error as possible.

Applicable Requirements

Requirements are set forth in the Scales Code relating to the application of tolerances to tests of scales. Three of these are directly relevant to vehicle and axle-load scales.

T.N.2. Tolerance Application.

T.N.2.1. General. - The tolerance values are positive (+) and negative (-) with the weighing device adjusted to zero at no load. When tare is in use, the tolerance values are applied from the tare zero reference; the tolerance values apply to certified test loads only.

T.N.2.3. Subsequent Verification Examinations. - For subsequent verification examinations, the tolerance values apply regardless of the influence factors in effect at the time of the conduct of the examination. (Also see G-N.2.)

T.N.2.4. Multi-Interval and Multiple Range (Variable Division-Value) Scales. - For multi-interval and multiple range scales, the tolerance values are based on the value of the scale division of the range in use.

NIST Handbook 44, Scales Code, Paragraphs T.N.2.1., T.N.2.3., and T.N.2.4

To meet the Handbook 44 requirement for accuracy, a scale must perform within specified tolerances in the circumstances of its actual use. During a field examination, tolerances are applied under the conditions in which the scale is found, regardless of environmental conditions (referred to as **influence factors** in Handbook 44), such as temperature, barometric pressure, electromagnetic or radio frequency interference, or power supply interruption.

During a test, tolerance values are applied to all indications and recorded representations of a scale, including indicators, printers, graduated balance indicators, and tare indicators.

As you will learn, Handbook 44 specifies several different tests of vehicle and axle-load scales. Each of these tests involves comparing the registration error under a specified set of conditions to the **applicable tolerance**. The applicable tolerance for a given test of a given scale is also specified in Handbook 44, but must be determined by the inspector, based upon the following factors:

- the amount of time that the scale has been in service since installation, a major overhaul, or a required repair,
- the amount of the test load, and
- the specific test being conducted.

The accuracy of many weighing and measuring devices, including scales, can be expected to deteriorate gradually in service. In order to allow a reasonable amount of use before devices have to be readjusted (and, thereby, keep the cost of compliance with weights and measures regulations reasonable), Handbook 44 specifies two sets of tolerances: one set, called **acceptance tolerances**, applies to devices that are "new" (as described below); the other set of tolerances, called **maintenance tolerances** apply to devices that have been in service for some time (see Handbook 44 paragraphs G-T.1. and G-T.2., discussed below).

G-T.1. Acceptance Tolerances. - Acceptance tolerances shall apply to:

(a) equipment to be put into commercial use for the first time;

(b) equipment that has been placed in commercial service within the preceding 30 days and is being officially tested for the first time;

(c) equipment that has been returned to commercial service following official rejection for failure to conform to performance requirements and is being officially tested for the first time within 30 days after corrective service;

(d) equipment that is being officially tested for the first time within 30 days after major reconditioning or overhaul; and

(e) equipment undergoing type evaluation.
(Amended 1989)

G-T.2. Maintenance Tolerances. - Maintenance tolerances shall apply to equipment in actual use, except as provided in G-T.1.

NIST Handbook 44, General Code, Paragraphs. G-T.1. and G-T.2.

Note that acceptance tolerances apply not only to devices that are literally "new," that is, those that have had 30 days or less of actual service, but also to those that have been returned to service after a major repair (in response to official rejection of the device) or reconditioning, and so should be expected to perform "like new." The values of acceptance tolerances are generally smaller than the values of maintenance tolerances: for scales, acceptance tolerances are one-half the value of the corresponding maintenance tolerances (see "**Tolerance Values**," below).

You will generally determine the time in service from the device owner. In some cases, you may wish to verify the service history by reviewing transaction records for the preceding 30 days to determine whether or not a scale has actually been in service during that time.

The Scales Code and the EPOs describe a number of different tests for vehicle and axle-load scales, all but one of which involve tolerances. Although every scale does not require all tests, and although most of the tests use the same tolerances, specified test loads vary, and this will affect tolerance values. You will, therefore, need to be able to determine the applicable tolerance value for each test, based upon specified parameters. These tests and their associated tolerances will be described later in this chapter.

Tolerance Values

The Scales Code specifies different tolerances for many scales, depending upon whether or not they are marked with an accuracy class. The tolerances for unmarked scales are summarized in Table T.1.1. for each type of scale. However, according to this table, the tolerances for marked and unmarked vehicle and axle-load scales are the same, that is, the tolerances specified for Class III L scales. The table is, therefore, not reproduced.

Maintenance Tolerance Values

Maintenance tolerances are specified in paragraph T.N.3.1. and Table 6.

T.N.3.1. Maintenance Tolerance Values. – The maintenance tolerance values are as specified in Table 6.

Table 6.
Maintenance Tolerances
(All values in this table are in scale divisions)

Tolerance in scale divisions				
	1	2	3	5
Class	Test Load			
I	0 - 50 000	50 001 - 200 000	200 001 +	
II	0 - 5 000	5 001 - 20 000	20 001 +	
III	0 - 500	501 - 2 000	2 001 - 4 000	4 001 +
IIII	0 - 50	51 - 200	201 - 400	401 +
III L	0 - 500	501 - 1 000	(Add 1d for each additional 500 d or fraction thereof)	

NIST Handbook 44, Scales Code Paragraph T.N.3.1. and Table 6.

Since vehicle and axle-load scales are Class III L devices, we are concerned with the last line in Table 6. As can be seen, for this class the tolerance value, shown on the top line, increases by 1 d for every additional 500d of test load. Since the maximum number of scale divisions for this class of scales is 10,000, such a scale, tested at full capacity, would have a tolerance of 20d.

Because the test of a scale involves a number of different test loads, including all the tolerance "break points" — the maximum load in each range (500d, 1,000d, 1,500d, and so on) — up to the amount of available test weights or the capacity of the scale, whichever is less, you will find that it saves time to determine the tolerances for each of the 500d ranges, up to the maximum load, as shown in the example in Figure 4-1 for a vehicle scale with 20-lb scale divisions.

Test Load in "d"	Maintenance Tolerance in "d"	Test Load in pounds	Maintenance Tolerance in pounds
0 - 500d	1	0 – 10,000 lb	20
501 - 1,000 d	2	10,020 – 20,000 lb	40
1,001 – 1500 d	3	20,020 – 30,000 lb	60
1,501 - 2,000 d	4	30,020 – 40,000 lb	80
2,001 - 2,500 d	5	40,020 – 50,000 lb	100
2,501 - 3,000 d	6	50,020 – 60,000 lb	120
and so on			

Figure 4-1. Maintenance Tolerance Table for Vehicle Scale with 20 lb Divisions

In some cases, however, a test load will not correspond to a tolerance break point — for example, if the test procedure calls for a test load that is equivalent to 600d. In that event, you will have to calculate the tolerance. To calculate the maintenance tolerance for a vehicle or axle-load scale, use the following steps.

- Determine the test load expressed in scale divisions (divide the test load by the scale division, converting the units of the test load to those of the scale division if necessary). For example, if 6 tons of test weights are to be applied to a scale with 20 lb divisions, the test load would be 12,000 lb ÷ 20 lb = 600d.

- Divide the test load by 500; if the result has a fractional remainder, round up to the next whole number. To continue with the same example, if 600d of test load will be applied, 600d ÷ 500 = 1.2, which rounds up to 2. This is the maintenance tolerance value in scale divisions, in this example, 2d.

Although this may seem complicated, you will find that in practice it is not; all you are doing is determining the number of whole 500 units in the test load.

Acceptance Tolerance Values

The acceptance tolerance for vehicle and axle-load scales is simply one-half the applicable maintenance tolerance.

T.N.3.2. Acceptance Tolerance Values. - The acceptance tolerance values shall be one-half the maintenance tolerance values.

NIST Handbook 44, Scales Code, Paragraph T.N.3.2.

For example, the acceptance tolerance for a scale with 20 lb scale divisions and a test load of 600d would be ½ x 2d = 1d (or 20 lb).

Decreasing-Load Test Tolerances

The Decreasing-Load Test is performed on all automatic-indicating scales. For vehicle and axle-load scales, the test load for the Decreasing-Load Test is one-half the maximum load applied during the Increasing-Load Test. The tolerances to be applied for the Decreasing-Load Test are those for Class III L scales specified in paragraph T.N.3.1. and Table 6 and paragraph T.N.3.2. of the Scales Code.

Agreement of Indications

When a scale system is equipped with multiple indicating and recording elements, all indicated and recorded representations of the same value must agree as closely as possible. As mentioned earlier, exact agreement between analog indications and digital indications or recorded representations within a system is not always possible, but the variation is strictly limited. Even two independent analog devices within the same system may disagree by a small amount. Because it is always desirable to limit such variation as much as possible, an additional tolerance applies to the agreement between indicators or recorded representations. Handbook 44 addresses agreement of indication requirements for three different scale designs.

The first is a scale with two or more indicating and/or recording elements that are intended to be used independently of one another. An example is a scale with a digital indicator and printer that also has a "standby" dial and printer to be used in case of a power failure or other failure of the digital indicator.

In this case, the tolerances are applied independently to each separate element or combination of elements. In other words, there is no tolerance for agreement between the indications.

T.N.4.1. Multiple Indicating/Recording Elements. - In the case of a scale or weighing system equipped with more than one indicating element or indicating element and recording element combination, where the indicators or indicator/recorder combination are intended to be used independently of one another, tolerances shall be applied independently to each indicator or indicator/recorder combination.
(Amended 1986)

NIST Handbook 44, Scales Code, Paragraph T.N.4.1.

The second design is a scale that is equipped with various means of indicating the weight of the same load, which are intended to be used in combination. An example is a weighbeam with counterpoise weights, a dial indicator with tare bars, or a weighbeam with an automatic-indicating attachment such as a weight-o-graph.

T.N.4.2. Single Indicating/Recording Element. - In the case of a scale or weighing system with a single indicating element or an indicating/recording element combination, and equipped with component parts such as unit weights, weighbeam and weights, or multiple weighbeams that can be used in combination to indicate a weight, the difference in the weight value indications of any load shall not be greater than the absolute value of the applicable tolerance for that load, and shall be within tolerance limits.
(Amended 1986)

NIST Handbook 44, Scales Code, Paragraph T.N.4.2.

In this case, all indications must be individually within the applicable tolerance and the indications or recorded representations produced by the different means must not differ by more than the absolute value of the applicable tolerance. For example, consider the following:

Type of indicator:	Dial with tare bars
Value of scale division:	20 lb
Test load:	20,000 lb
Maintenance tolerance value:	2d or 40 lb
Acceptable tolerance range:	19,960 lb to 20,040 lb
Dial indication:	20,020 lb

In this case, the tare bar could indicate no more than 20,040 pounds (20,020 + 40 = 20,060; however, 20,060 is not within the acceptable tolerance range) and no less than 19,980 pounds (20,020 - 40 = 19,980 lb) in order for the scale to meet the agreement requirement in T.N.4.2. and be within the applicable tolerance. If the dial had indicated 20,000 pounds, the tare bar reading still could have been no more than 20,040 pounds, but the minimum reading could have been 19,960 pounds.

Finally, the third design is a scale equipped with two analog indicators as part of the same element, which are used to indicate the same load. Usually, one indicator is provided for the customer and one is provided for the device operator. An example would be a vehicle scale with twin dials, one on the front and one on the back of the indicator.

T.N.4.3. Single Indicating Element/Multiple Indications. - In the case of an analog indicating element equipped with two or more indicating means within the same element, the difference in the weight indications for any load other than zero shall not be greater than one-half the value of the scale division (d) and be within tolerance limits.
(Amended 1986)

NIST Handbook 44, Scales Code, Paragraph T.N.4.3.

In this case, the readings of both indicators must be within tolerance and must agree within one-half the value of the scale division. If you are testing a scale with a scale division value of 20 pounds, the maximum difference permitted between the two dial indications is 10 pounds. For example, with a test load of 20,000 pounds on the scale and a maintenance tolerance of 40 pounds, if the indicator of one dial was on the 20,020-pound graduation and the indicator of the other dial was half-way between the 20,020-pound and the 20,040-pound graduations, the indications would both be within tolerance and they would agree within the 10-pound limit; however, if the indicator of the second dial was closer to the 20,040 graduation or on that graduation, the indication would still be within tolerance but would not meet the agreement requirement specified in paragraph T.N.4.3.

Tolerances on Shift Tests

In the shift test, two different loads not exceeding the Concentrated Load Capacity or section capacity are applied at various points on the load-receiving element, usually over each section and sometimes also at the midpoints between the sections. At each point, the indicated and recorded weights are observed. Each of the readings must be within the applicable tolerance.

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)

absolute value. – The absolute value of a number is the magnitude of that number without considering the positive or negative sign.

NIST Handbook 44, Scales Code, Paragraph T.N.4.4. and Appendix D, Definitions

In addition, the range of weight values obtained from the separate weighings may not exceed the absolute value of the applicable maintenance tolerance. As described in NIST Handbook 44, Appendix D, Definitions, the absolute value of a number is that number without any plus ("+") or minus ("-") signs. For example, the absolute value of a maintenance tolerance value of +/- 60 lb is 60 lb (without any signs). To determine the range of a group of section test results, subtract the smallest from the largest indicated section weight; the result is the range, which must not exceed the absolute value of the maintenance tolerance.

For example, consider a four-section scale with a CLC of 50,000 lb and a 20-lb scale division. A total of 30,000 lb of certified test weights is available for the test. The scale has been in service for more than 30 days; therefore, maintenance tolerances apply. If the sections are tested with the entire available weight, the tolerance will be (30,000 lb ÷ 20 lb) ÷ 500 = 3d = 60 lb. Suppose the following weights are registered:

Section 1	30,040 lb
Section 2	29,980 lb
Section 3	30,000 lb
Section 4	29,960 lb

Since readings between 29,940 lb and 30,060 lb meet the maintenance tolerance for this test, each individual section is so far in compliance. However, the range of values is 30,040 - 29,960 = 80 lb. Since this exceeds the tolerance of 3d = 60 lb, the scale fails to meet that portion of the requirement.

Repeatability

A fundamental criterion for accuracy of a weighing or measuring device is its **repeatability**, that is, its ability to reproduce the same indicated measurement of the same test load under reasonably similar conditions. Again, the absolute value of the applicable maintenance tolerance is applied as a tolerance to the difference between successive weighings of the same load under similar conditions.

> **T.N.5. Repeatability.** - The results obtained from several weighings of the same load under reasonably static test conditions shall agree within the absolute value of the maintenance tolerance for that load, and shall be within applicable tolerances.

NIST Handbook 44, Scales Code, Paragraph T.N.5.

For example, consider a 100,000 x 20 lb scale with a 20,000 lb test load applied. If a weight value of 19,960 lb is displayed under one application of the 20,000 lb load, and a repeat application of the same load displays 20,040 lb, the individual readings are within the maintenance tolerance of +/- 40 lb; however the scale is not within tolerance for repeatability. The repeatability tolerance, which is the absolute value of the maintenance tolerance, is 40 lb; the difference in two repeat readings in the example is 80 lb (20,040 lb - 19,960 lb = 80 lb).

Note that T.N.5. specifies the absolute value of the maintenance tolerance, whether or not the system is being tested for acceptance. Here, a situation may arise where successive weighings of the same test load meet the repeatability requirement, even though they fail to meet the tolerance requirement. For example, on the scale just described, if successive weighings give indications of 20,000 lb and 20,040, the second weighing exceeds the acceptance tolerance for the test (20 lb), even though the difference between the weights is within the tolerance for repeatability (40 lb).

Sensitivity Requirement (SR)

Nonautomatic indicating elements, such as weighbeams, are required to meet a minimum requirement for the degree of responsiveness to a change in load. According to Handbook 44, the **sensitivity requirement** (**SR**) is "the minimum change in position of rest of the indicating element or elements of the scale in response to the increase or decrease, by a specified amount, of the test load on the load-receiving element of the scale" (for example, the minimum movement of a dial pointer when a specified amount of weight is applied to the scale).

Although not precisely a tolerance, the SR has traditionally been included in the tolerance section of the Scales Code. The test loads for the sensitivity test are given in terms of the scale division and, consequently,

must be converted to pounds prior to the test. The test loads for the SR test for marked and unmarked scales are identical, but are specified in different paragraphs of the Scales Code. The test loads for unmarked vehicle and axle-load scales is set forth in T.2.7.; the test load for marked scales in T.N.6.1.

T.2.7. [Sensitivity test load for unmarked] **Vehicle, Axle-Load, Livestock, and Animal Scales.**

T.2.7.1. Equipped with Balance Indicators. 1d

T.2.7.2. Not Equipped with Balance Indicators. 2d or 0.2 percent of the scale capacity, whichever is less.

* * *

T.N.6.1. [Sensitivity] **Test Load**

(a) The test load for sensitivity for nonautomatic-indicating vehicle, axle-load, livestock,. and animal scales shall be 1d for scales equipped with balance indicators, and 2d or 0.2 percent of the scale capacity, whichever is less, for scales not equipped with balance indicators.

NIST Handbook 44, Scales Code, Paragraphs T.2.7. and T.N.6.1. (a)

The specified changes in equilibrium corresponding to the specified test loads for unmarked and marked scales are similar, and for all practical purpose identical, except for one detail. The paragraphs from the Scales Code (T.3. and T.N.6.2.) are printed side by side on the next page. Figure 4-2 summarizes the requirements.

	Test Load—Marked and Unmarked	**Equilibrium Change Unmarked Scales**	**Equilibrium Change Marked Scales**
With Balance Indicator	1d	Greater of 0.25 inch change in position or 1 graduation or width of target area	Same as unmarked except ***0.20*** inch change in position
With Trig Loop but no Balance Indicator	Lesser of 2d or 0.2% of scale capacity (whichever, is less)	Tip of beam moves from center of trig loop to the top or bottom	Same as unmarked
With neither Trig Loop nor Balance Indicator	Lesser of 2d or 0.2% of scale capacity (whichever, is less)	Position of weighbeam or lever system moves from midway between stops to either limit of motion	Same as unmarked

Figure 4-2. Sensitivity Requirements

[For Unmarked Scales]

T.3. Sensitivity Requirement, Equilibrium Change Required. - The minimum change in equilibrium with test loads equal to the values specified in T.2. shall be as follows:

(a) Scale With a Trig Loop but Without a Balance Indicator. - The position of rest of the weighbeam shall change from the center of the trig loop to the top or bottom, as the case may be.

* * *

(c) Scale With a Single Balance Indicator and Having a Nominal Capacity of 500 Pounds or Greater. - The position of rest of the indicator shall change 0.25 (1/4) inch or one division on the graduated scale or the width of the central target area, whichever is greater. However, the indicator on a batching scale shall change 0.125 (1/8) inch or one division on the graduated scale, whichever is greater.

* * *

(e) Scale With Neither a Trig Loop Nor a Balance Indicator. - The position of rest of the weighbeam or lever system shall change from the horizontal, or midway between limiting stops, to either limit of motion.

[For Marked Scales]

T.N.6.2. Minimum Change of Indications. - The addition or removal of the test load for sensitivity shall cause a minimum permanent change as follows:

(a) For a Scale with a Trig Loop but Without a Balance Indicator. - The position of the weighbeam shall change from the center to the outer limit of the trig loop.

(b) For a Scale With a Balance Indicator. - The position of the indicator shall change one division on the graduated scale, the width of the central target area, or the applicable value as shown below, whichever is greater:

Scale of Class III, III L, or IIII with a maximum capacity of more than 70 pounds (30 kg): 0.20 inch (5mm);

(c) For a Scale Without a Trig Loop or a Balance Indicator. - The position of rest of the weighbeam or lever system shall change from the horizontal or midway between limiting stops to either limit of motion.

NIST Handbook 44, Scales Code, Paragraphs T.3. and T.N.6.2.

Discrimination

The discrimination test for automatic-indicating elements is analogous to the sensitivity test for nonautomatic-indicating elements. However, for the discrimination test, the addition or subtraction of a specified test load must produce a minimum change in indication. There are separate specifications for analog and digital indicators (see paragraph T.N.7. below). Again, the specified values are expressed in terms of scale divisions, and so must be converted to pounds. The determination of the zone of uncertainty will be discussed further in Chapter 6.

T.N.7. Discrimination

T.N.7.1. Analog Automatic Indicating (i.e., Weighing Device with Dial, Drum, Fan, Etc.). -A test load equivalent to 1.4d shall cause a change in the indication of at least 1.0d. (See N.1.5.)

T.N.7.2. Digital Automatic Indicating. - A test load equivalent to 1.4d shall cause a change in the indicated or recorded value of at least 2.0d. This requires the zone of uncertainty to be not greater than 0.3 times the value of the scale division. (See N.1.5.1.)

NIST Handbook 44, Scales Code, Paragraphs T.N.7., T.N.7.1., and T.N.7.2.

Maximum and Minimum Test Loads

The tolerances described in this chapter are determined according to the test load that is applied. In the case of large-capacity scales like vehicle and axle-load scales, test loads are often limited by the available certified test weights. As explained in Chapter 2, Handbook 44 specifies the minimum test weights and test loads required for testing different capacity scales.

N.3. Minimum Test Weights and Test Loads[2]. - The minimum test weights and test loads for in-service tests (except railway track scales) are shown in Table 4. [See Table 4 for footnote [2].]
(Added 1984) (Amended 1988)

NIST Handbook 44, Scales Code, Paragraph N.3.

Table 4 is reproduced on the next page along with the accompanying paragraph N.3. Since most vehicle scales have capacities of more than 40,000 lb, the minimum test weights, according to Table 4, are 12.5 percent of the scale capacity or 10,000 lb, whichever is greater. For a vehicle scale with a capacity of 200,000 lb, the minimum test weight would therefore be $0.125 \times 200{,}000 = 25{,}000$ lb.

In addition, a larger minimum **test load** of 25 percent of the scale capacity is required. The test load consists of certified weights plus any other non-certified weights or loads that are used in testing (for example, a vehicle used in the strain-load load test of a vehicle scale). Thus, a minimum test load for a scale with 200,000 capacity would be $0.25 \times 200{,}000 = 50{,}000$, at least half of which would be certified test weights.

Examples used in this and subsequent chapters will assume that 30,000 lb of certified test weights are available and that additional non-certified weights are available to obtain a total test load of 60,000 lb.

While having minimum test weights and loads is essential to conducting effective tests of vehicle and axle-load scales in the field, it is also essential that test loads not be applied in a manner that places a damaging strain on the scale. Specific guidelines for applying test loads are given in Chapter 6. However, an essential limitation should be observed in all test situations:

- The test load applied to a scale section, or to the span of a scale deck between sections, should never exceed the Concentrated Load Capacity that is required to be marked by the manufacturer on scales manufactured after January 1, 1989, or the section capacity specified by the manufacturer of a scale manufactured prior to that date.

N.3. Minimum Test Weights and Test Loads[2]. - The minimum test weights and test loads for in-service tests (except railway track scales) are shown in Table 4. [See Table 4 for footnote [2].]
(Added 1984) (Amended 1988)

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

Device capacity	Minimums (in terms of device capacity)		(where practicable)
	Test weights (greater of)	Test loads[2]	
0 to 150 kg (0 to 300 lb)	100 %		
151 to 1 500 kg (301 to 3 000 lb)	25 % or 150 kg (300 lb)	75 %	Test weights to dial face capacity, 1 000 d, or test load to used capacity, if greater than minimums specified
1 501 to 20 000 kg (3 001 to 40 000 lb)	12.5 % or 500 kg (1 000 lb)	50 %	
20 001 kg+ (40 001 lb+)	12.5 % or 5 000 kg (10 000 lb)	25 %[3]	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 known test weights or substitution test load.
(Amended 1988, 1989 and 1994)

NIST Handbook 44, Scales Code, Paragraph N.3. and Table T.4.

Since the nominal capacity of a scale marked with an accuracy class must be less than the sum of the capacities of the scale sections (specifically, less than or equal to the CLC times the number of sections minus 0.5, as explained in Chapter 3), a test load equal to the full capacity may be distributed over the entire deck, provided that the maximum load on any one section or between sections is not exceeded.

Substitution Test

In a substitution test, unknown material or objects are substituted for known test weights as described in NIST Handbook 44 Scales Code paragraph N.1.11. and in Appendix D, Definitions. The tolerances are applied to the scale based on the substitution test load as noted in Scales Code paragraph T.N.3.11. This process is used as part of the increasing load test when sufficient weights are unavailable to reach the required test load specified in Table 4. The substitution process shall be repeated no more than three times.

In the substitution process, known test weights are placed on the scale; a scale reading is taken using error weights to determine the exact scale indication; the reading is noted; and the known test weights are removed. Next, unknown material or objects are added to the scale until the scale indication reads the same as when the known test weights were on the scale; error weights are again used to ensure the reading is duplicated. This process represents one substitution of the known test weights.

Once the substitution process has been completed, the test can be continued using the known test weights. When all of the known test weights have once again been applied, the scale reading is taken using error weights as described above and the known test weights are removed. Additional unknown material or objects are substituted for the known test weights using the same process as described above.

N.1.11. Substitution Test. - In the substitution test process, material or objects are substituted for known test weights, or a combination of known test weights and previously quantified material or objects, using the scale under test as a comparator. Additional test weights or other known test loads may be added to the known test load to evaluate higher weight ranges on the scale.

T.N.3.11. Tolerances for Substitution Test. - Tolerances are applied to the scale based on the substitution test load.

substitution test. – A scale testing process used to quantity the weight of material or objects for use as a known test load.

substitution test load. – 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.

NIST Handbook 44, Scales Code, Paragraphs N.1.11. and T.N.3.11. and Appendix D, Definition

Strain-Load Test

In a strain-load test, an unknown quantity of material or objects are used to establish a reference load point to which test weights or a combination of test weights and substitution test loads are added. This process is used when available test weights are less than maximum capacity of a vehicle or axle-load scale and another means must be found to test the upper portion of the scale's capacity. This process is referenced in NIST Handbook 44 Scales Code paragraph N.1.12. and in Appendix D, Definitions. The tolerances are applied to the scale based on the known test weights or substitution test load as noted in Scales Code paragraph T.N.3.12.

The strain-load test is conducted by removing all loads from the scale and zeroing the scale. Next, an unknown load is placed on the scale and error weights are used to establish a beginning reference load point. Known test weights are then applied to the scale and error weights used to determine the resulting scale reading. This resulting scale reading is compared with the beginning reference load point, and the difference between the two is determined. The error is determined by comparing this difference with the known test load that was applied to the scale. The process for conducting a strain-load test is discussed in more detail in Chapter 6.

N.1.12. Strain-Load Test. - In the strain-load test procedure, an unknown quantity of material or objects are used to establish a reference load or tare to which test weights or substitution test loads are added.

T.N.3.12. Tolerances for Strain-Load Test. - The tolerances apply only to the test weights or substitution test load.

Strain-load test. – The test of a scale beginning with the scale under load and applying known test weights to determine accuracy over a portion of the weighing range. The scale errors for a strain-load test are the errors observed for the known test loads only. The tolerances to be applied are based on the known test load used for each error that is determined.

NIST Handbook 44, Scales Code, Paragraphs N.1.12. and TN.3.12. and Appendix D, Definition

Constructing A Tolerance Worksheet

It is good practice to make all tolerance determinations before beginning any test. This will permit you to plan the test to make the most efficient use of available test weights if they are less than the capacity of the scale and will help insure that nothing important is overlooked. One effective approach is to use tolerance worksheets, which not only record applicable tolerance values but also break the test down into its essential components. Three sample worksheets have been developed for use in this module. Blank worksheets are reproduced in Appendix C. You should find that these worksheets, along with the EPOs, make the pretest determinations portion of the examination as efficient as possible.

One worksheet is provided for each of the following types of vehicle and axle-load scales:

- full capacity weighbeams
- mechanical dials
- electronic scales

Separate worksheets have been developed for these different types of scales even though most tolerances are similar because of differences in test application and procedure. You will learn about these topics in the next chapters. At present, you should concentrate on learning how to fill out the worksheets. Examples of completed worksheets are given below, and a partially completed example is provided on which to practice the tolerance determinations. You will be given additional opportunities to practice and review worksheets with your instructor.

Before turning to the examples, you should be aware that the test method known as "tolerance testing" is employed exclusively in this manual, and it is recommended for use in field examinations. In tolerance testing you determine by direct reading whether or not the displayed weight value at each test load is within tolerance for that test load. This will not define the exact amount of scale error in each case, but does determine whether or not the scale performance is within acceptable limits.

Some jurisdictions use "error testing." In this method, small test weights are used to determine the exact amount of error at a particular test load. Although this method provides more accurate indications of the error than tolerance testing, most jurisdictions use tolerance testing because:

- it takes less time,
- official actions are based on devices being in or out of tolerance, not on the exact amount of error, and

- it is less affected by environmental factors such as wind because larger test loads are used.

Consequently, tolerance testing procedures are used in this module.

In tolerance testing, the range of weight values that are within tolerance for each test load is called the "acceptable range of scale indication." Weight values are determined by direct reading from the indicator. All weight values must fall within the "acceptable range of scale indication." If any of the test values fall outside that range, the scale fails to meet the tolerance requirements of Handbook 44.

For example, when a 10,000-lb test load is placed on the scale, and the maintenance tolerance is 20 lb, the acceptable range of scale indication is:

10,000 lb - 20 lb = 9,980 lb
10,000 lb + 20 lb = 10,020 lb.

Any test value in the range from 9,980 lb to 10,020 lb is acceptable. A value above or below that range means the scale is out of tolerance and cannot be approved.

It is good practice to calculate the "acceptable range of scale indication" as a part of the pretest determination of tolerances. The sample worksheets provide space for entering those values.

Sample Tolerance Worksheets

The worksheets are organized in two sections, as can be seen in Figure 4-3. In the upper section of the worksheet, along the left-hand side, are listed the various capacities of the scale, the value and number of scale divisions (d and n), and the total available certified test weights. In addition, space is provided to record whether the scale is marked III L and whether acceptance or maintenance tolerances are applicable. You should fill in data in the spaces provided.

The right-hand portion of the top section presents a summary of the weights that correspond to the 500d increments that are used to determine tolerances in Table 6. The first value, 500d, is calculated by multiplying the value of the scale division by 500. Subsequent values are multiples of 500d, and can be easily filled in. To avoid confusion, values should not be filled in above the amount of available test weights. This summary will make it easier to determine specific tolerances as you continue filling in the worksheet.

The lower portion of the worksheet summarizes test loads, tolerances, and acceptable ranges of scale indications for each of the tests prescribed in the EPOs. You start by filling in the test loads column. As you can see in Figure 4-3, many of the test loads correspond to whole or fractional capacities (one-half and full fractional bar capacity, section capacity, etc.). Where reference is made to the **tolerance break point**, these are the largest values in the test load ranges in Table 6. Tests are made at tolerance break points because at that end of the range the tolerance is smallest in proportion to the test load (0.2 percent). Keep in mind the minimum test weights and test loads specified in Table 4 of the Scales Code as you complete the worksheet.

The notes in the table state that a minimum test of a Class III L scale shall consist of one test from zero to at least 25 percent of the scale capacity and then one strain-load test to at least the **used capacity** of the device. Used capacity refers to the largest load normally weighed on the scale. This can be determined by asking the scale operator or owner about the typical use of the scale, considering the application of the scale, and observing the vehicles being weighed. It will not be necessary to include the used capacity on the worksheet; instead, under the Strain-Load Test, you will enter the amount of known (certified) test weights available to conduct the test.

When the test loads column is filled in, the remainder of the worksheet determinations are mechanical:

- Fill in the second column, **Tol. In "d"** by consulting Table 6 for the test loads listed in the first column, except for the **Zero-Load Balance Change**. This value will always be 1d for maintenance tests and 0.5d for acceptance tests (according to N.1.9.).

- Fill in the third column, **Tol. In Pounds**, by multiplying the value in the second column by the scale division and recording the result.

- Fill in the fourth column, **Acceptable Range of Scale Indication, Minimum Pounds**, by subtracting the value in the third column (tolerance in pounds) from the value in the first column (test load) and recording the result.

- Fill in the fifth column, **Acceptable Range of Scale Indication, Maximum Pounds**, by adding the value in the third column to the value in the first column.

You will learn how to use the completed worksheet as an aid in conducting the tests in Chapter 6. For the present, review each of the following examples to make sure that you understand how the tolerances are determined. Begin by reading the notes which precede each example, which are intended to clarify some of the items relating to test objectives and procedures (these topics will be reviewed later in the module). When you have reviewed each of the three examples, proceed to Example 4 and complete the blank worksheet that follows the example (except that, you do not have to complete the "Acceptable Range of Scale Indication" columns). Make notes of any questions you have, so that you can go over them with your instructor.

Example 1

Tolerance Worksheet for a Scale with a Full-Capacity Weighbeam

Scale Data

Scale with full capacity beam
Scale capacity: 100,000 × 10 lb (fractional bar 990 lb × 10 lb)
Section capacity: 50,000 lb
Not marked with accuracy class
Since the scale has been in service over 30 days since installation or repairs, maintenance tolerances apply.

Available certified test weights: 30,000 lb

Notes

Increasing-Load Test and Shift Test Tolerances. The Increasing-Load Test determines whether or not the scale performs accurately as larger loads are applied to the scale. Use tolerances from Table 6 for the Increasing-Load Test. List test loads at the tolerance break points to the limits of available test weights or CLC or section capacity. The shift test determines the performance of the scale under off-center loading and provides an opportunity to check the agreement of scale indications. Table 6 values apply to each reading taken during the shift test; however, the range of results obtained during the test must not exceed the absolute value of the maintenance tolerance applicable. The shift test should be conducted with test loads equal to one-half and the full CLC or section capacity if an adequate amount of certified test weights (equivalent to the CLC or section capacity) is available; if not, the test should be conducted with one-half and the full amount of certified test weights.

Strain-Load Test Tolerances. With vehicle and axle-load scales, certified test weights to the capacity of the scale are seldom available. In the strain-load test, a heavy load — often a vehicle — is applied and standard test weights are added. Tolerances are applied only to the "added weight value" of the standard weights applied. A full explanation of procedures for the Strain-Load Test will be presented in Chapter 6.

Zero-Load Balance Change. When all test load is removed from the scale deck, the scale should return to zero within the tolerance for zero load.

TOLERANCE WORKSHEET
FULL CAPACITY BEAM - VEHICLE OR AXLE-LOAD SCALE

BEAM CAPACITY:	100,000 lb	500 d -	5,000 lb
FRACTIONAL BAR CAPACITY	990 lb	1000 d -	10,000 lb
CLC or SECTION CAPACITY:	50,000 lb	1500 d -	15,000 lb
SCALE CAPACITY:	100,000 lb	2000 d -	20,000 lb
VALUE OF SCALE DIVISION:	10 lb	2500 d -	25,000 lb
NUMBER OF SCALE DIVISIONS:	10,000	3000 d -	30,000 lb
AVAIL. CERT. TEST WEIGHTS:	30,000 lb	3500 d -	_____ lb

MARKED III L ___ yes X no
TOLERANCE TO BE APPLIED: ___ ACCEPTANCE X MAINTENANCE

TEST LOAD DESCRIPTION	TEST LOAD POUNDS	TOL. IN "d"	TOL. IN POUNDS	ACCEPTABLE RANGE OF SCALE INDICATION MINIMUM POUNDS	MAXIMUM POUNDS
INCREASING-LOAD AND SHIFT TEST					
at 1/2 fractional bar cap.:	500	1	10	490	510
at full fractional bar cap.:	990	1	10	980	1,000
at each tol. break point:	5,000	1	10	4,990	5,010
	10,000	2	20	9,980	10,020
	____	____	____	____	____
SHIFT TEST					
at 1/2 CLC, sect. cap., or test load:	15,000	3	30	14,970	15,030
range of results must be within:		3	30		
CONTINUE INCREASING-LOAD AND SHIFT TEST					
at each tol. break point:	20,000	4	40	19,960	20,040
	25,000	5	50	24,950	25,050
	30,000	6	60	29,940	30,060
	____	____	____	____	____
	____	____	____	____	____
	____	____	____	____	____
	____	____	____	____	____
	____	____	____	____	____
	____	____	____	____	____
	____	____	____	____	____
SHIFT TEST					
at CLC, sect. cap. or test load:	30,000	6	60	29,940	30,060
range of results must be within:		6	60		
STRAIN-LOAD TEST					
certified test load only:	30,000	6	60	29,940	30,060
ZERO-LOAD BALANCE CHANGE:	0	1	10	-10	10

Figure 4-3. Sample Tolerance Worksheet, Scale With a Full Capacity Weighbeam

Example 2

Tolerance Worksheet for Mechanical Dial Scale

Scale Data

Vehicle scale equipped with dial and printer
Dial capacity: 20,000 lb
Equipped with four 20,000-lb unit weights
Section capacity: 50,000 lb
Scale capacity: 100,000 lb
Scale division: 20 lb
Not marked with accuracy class
Since the scale has just gone back into service last week after being repaired, acceptance tolerances apply.

Available certified test weights: 30,000 lb

Notes

Increasing-Load Test. Test at least at each quarter of the dial face. Also test every unit weight possible, at least one test load per unit weight.

Decreasing-Load Test. This test is performed only for automatic-indicating scales. It tests the ability of the scale to perform as strain is gradually removed. Comparison of performance on this test with performance on the Increasing-Load Test may indicate the condition of the equipment; the greater the difference, the stronger the indication that system components are worn or fittings are loose.

TOLERANCE WORKSHEET
MECHANICAL DIAL - VEHICLE OR AXLE-LOAD SCALE

DIAL CAPACITY:	20,000 lb	500 d -	10,000 lb	
CLC or SECTION CAPACITY:	50,000 lb	1000 d -	20,000 lb	
SCALE CAPACITY:	100,000 lb	1500 d -	30,000 lb	
VALUE OF SCALE DIVISION:	20 lb	2000 d -	____ lb	
NUMBER OF SCALE DIVISIONS:	5,000	2500 d -	____ lb	
AVAIL. CERT. TEST WEIGHTS:	30,000 lb	3000 d -	____ lb	
MARKED III L ___ yes	X no	3500 d -	____ lb	
TOLERANCE TO BE APPLIED:	X ACCEPTANCE	___ MAINTENANCE		

TEST LOAD DESCRIPTION	TEST LOAD POUNDS	TOL. IN "d"	TOL. IN POUNDS	ACCEPTABLE RANGE OF SCALE INDICATION MINIMUM POUNDS	MAXIMUM POUNDS
INCREASING-LOAD AND SHIFT TEST					
at 1/4 dial capacity:	5,000	0.5	10	4,490	5,010
at 1/2 dial capacity:	10,000	0.5	10	9,990	10,010
at 3/4 dial capacity:	15,000	1.0	20	14,980	15,020
at full dial capacity:	20,000	1.0	20	19,980	20,020
at each unit weight:	20,000	1.0	20	19,980	20,020
	____	____	____	____	____
SHIFT TEST					
at 1/2 CLC, sect. cap., or test load:	15,000	1.0	20	14,980	15,020
range of results must be within:		2.0	40		
CONTINUE INCREASING-LOAD AND SHIFT TEST					
at each tol. break point:	30,000	1.5	30	29,970	30,030
	____	____	____	____	____
	____	____	____	____	____
	____	____	____	____	____
SHIFT TEST					
at CLC, sect. cap., or test load cap.:	30,000	1.5	30	29,970	30,030
range of results must be within:		3.0	60		
DECREASING-LOAD TEST					
at one-half avail. load:	15,000	1.0	20	14,980	15,020
STRAIN-LOAD TEST					
certified test load only:	30,000	1.5	30	29,970	30,030
ZERO-LOAD BALANCE CHANGE:	0	0.5	10	-10	10

Figure 4-4. Sample Tolerance Worksheet, Mechanical Dial Scale

Example 3

Scale Equipped with Electronic Digital Indicator

Scale Data

Electronic digital vehicle scale
CLC: 50,000 lb
Scale capacity: 100,000 lb
Scale division: 20 lb
The scale is marked accuracy class III L
It has been in service more than 6 months; therefore, maintenance tolerances will apply.

Available certified test load: 30,000 lb

Tests are similar to those for scales with mechanical dial indicators; except that, test loads for the Increasing-Load Test are set at tolerance break points.

TOLERANCE WORKSHEET
ELECTRONIC - VEHICLE OR AXLE-LOAD SCALE

CLC or SECTION CAPACITY:	50,000 lb	500 d -	10,000 lb
SCALE CAPACITY:	100,000 lb	1000 d -	20,000 lb
VALUE OF SCALE DIVISION:	20 lb	1500 d -	30,000 lb
NUMBER OF SCALE DIVISIONS:	5,000	2000 d -	____ lb
AVAIL. CERT. TEST WEIGHTS:	30,000 lb	2500 d -	____ lb
MARKED III L	X yes ___ no	3000 d -	____ lb
		3500 d -	____ lb
TOLERANCE TO BE APPLIED:	___ ACCEPTANCE	X MAINTENANCE	

TEST LOAD DESCRIPTION	TEST LOAD POUNDS	TOL. IN "d"	TOL. IN POUNDS	ACCEPTABLE RANGE OF SCALE INDICATION MINIMUM POUNDS	MAXIMUM POUNDS
INCREASING-LOAD AND SHIFT TEST at each tol. break point:	10,000	1	20	9,980	10,020
	____	___	___	___	___
	____	___	___	___	___
SHIFT TEST at 1/2 CLC, sect. cap., or test load:	15,000	2	40	14,960	15,040
range of results must be within:		2	40		
CONTINUE INCREASING-LOAD AND SHIFT TEST at each tol. break point:	20,000	2	40	19,960	20,040
	30,000	3	60	29,940	30,060
	____	___	___	___	___
	____	___	___	___	___
SHIFT TEST at CLC, sect. cap., or test load cap.:	30,000	3	60	29,940	30,060
range of results must be within:		3	60		
DECREASING-LOAD TEST at one-half avail. load:	15,000	2	40	14,960	15,040
STRAIN-LOAD TEST certified test load only:	30,000	3	60	29,940	30,060
ZERO-LOAD BALANCE CHANGE:	0	1	20	-20	20

Figure 4-5. Sample Tolerance Worksheet, Scale With Electronic Digital Indicator

Example 4

Electronic Vehicle Scale

Scale Data

Electronic digital vehicle scale
Section Capacity: 70,000 lb
Scale Capacity: 100,000 lb
Scale Division: 20 lb
The scale is not marked with an accuracy class designation.
The scale is being returned to service after major overhaul; therefore, acceptance tolerances will apply.

Available certified test load: 30,000 lb

Based upon this data, complete the tolerance worksheet on the next page.

TOLERANCE WORKSHEET
ELECTRONIC — VEHICLE OR AXLE-LOAD SCALE

CLC or SECTION CAPACITY:	____ lb	500 d -	____ lb
SCALE CAPACITY:	____ lb	1000 d -	____ lb
VALUE OF SCALE DIVISION:	____ lb	1500 d -	____ lb
NUMBER OF SCALE DIVISIONS:	____	2000 d -	____ lb
AVAIL. CERT. TEST WEIGHTS:	____ lb	2500 d -	____ lb
MARKED III L ___ yes ___ no		3000 d -	____ lb
		3500 d -	____ lb

TOLERANCE TO BE APPLIED: ___ ACCEPTANCE ___ MAINTENANCE

TEST LOAD DESCRIPTION	TEST LOAD POUNDS	TOL. IN "d"	TOL. IN POUNDS	ACCEPTABLE RANGE OF SCALE INDICATION MINIMUM POUNDS	MAXIMUM POUNDS
INCREASING-LOAD AND SHIFT TEST at each tol. break point:	____	___	____	____	
	____	___	____	____	
	____	___	____	____	
SHIFT TEST at 1/2 CLC, sect. cap., or test load:	____	___	____	____	
range of results must be within:		___			
CONTINUE INCREASING-LOAD AND SHIFT TEST at each tol. break point:	____	___	____	____	
	____	___	____	____	
	____	___	____	____	
	____	___	____	____	
SHIFT TEST at CLC, sect. cap., or test load cap.:	____	___	____	____	
range of results must be within:		___			
DECREASING-LOAD TEST at one-half avail. load:	____	___	____	____	
STRAIN-LOAD TEST certified test load only:	____	___	____	____	
ZERO-LOAD BALANCE CHANGE:	____	___	____	____	

Summary

In an ideal situation, a vehicle or axle-load scale would perform without error at every weight value throughout its range. In practice, however, the precision of construction and adjustment of equipment will vary. Repeated use of the equipment will cause wear at critical points, thus changing the accuracy of weight values delivered. Consequently, official tolerance values are set that are small enough to protect all parties, yet large enough to insure that purchase and maintenance of equipment will not be unreasonably costly.

Before you can test a scale for compliance with allowable tolerance values, you must determine the proper tolerances to apply. Applicable tolerances are based upon the amount of time in service since installation, a major repair, or corrective action, the size of test loads, and test parameters.

It is good practice to construct a tolerance worksheet that shows applicable tolerances for different test loads and acceptable ranges of scale indications.