Product test load development

References

Field Inspection Manual for Non-Automatic Weighing Devices
Field Inspection Manual for Automatic Weighing Devices

Purpose

When inspecting some types of weighing devices or systems, it is best to use test loads comprising known quantities of product that the device is designed to weigh. These tests are referred to as product tests or material tests. The known quantity of product developed to perform these tests is referred to as the product test load or material test load. In order to ensure that the uncertainty of the product test load does not significantly affect the test results, the product test load must be carefully developed using this procedure.

General

Product test loads are typically comprised of a bulk commodity representative of the type of product to be weighed by the device. When the same material is not available, care must be taken to select a material with similar densities and flow characteristics as the material intended to be measured.

The weight of the product test load can either be predetermined or can be an unknown quantity of material which is passed through the system, recovered and then weighed. In either case, the amount of material required to conduct a suitable test can be very large and appropriate arrangements must be made to move this material around the site.

In the case of a preweighed test load, it is important that the load is stored so as to ensure that the entire preweighed test load, and no extra material, is measured by the device under test (DUT).

In the case of a post-weighed test load, it is important to ensure that all material measured by the DUT is accounted for in the final test load. If multiple trucks or rail cars are required to receive the material, it is relatively easy to lose material in the process.

In both cases, utmost care must be exercised to ensure that no material is lost during the test, as this will invalidate the results. The product test load must be determined immediately before or after the test. The material used for the product test load must be protected from the elements and must not be allowed to absorb or lose significant amounts of moisture between development of the product test load and testing the device. Special care must be taken on days with rain, snow, extreme heat or wind.

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In some cases, the product test load will consist of a number of discrete items as opposed to a bulk commodity. These test loads are typically used when assessing the performance of an automatic catch weight device. While it is easier to weigh and account for discrete items, care must be taken to ensure that each item is associated with its correct weight value. This is critical when many items have similar weight values. Uniquely identifying each test load item is the easiest way to ensure that they are associated with the correct weight value.

A product test is used to determine the accuracy of a weighing device or system that cannot be adequately assessed using mass standards. The product test can be the only test to which the device is subject or it can be used in addition to testing with mass standards.

Product test loads are typically developed on a separate reference scale rather than on the DUT. Typically, the reference scale will be of a higher accuracy and resolution than the DUT; however, in exceptional circumstances, it may be possible to use a reference scale whose interval is the same as the interval of the device being tested ($d_{REF} = d_{DUT}$). In very rare cases, where a suitable reference scale is not available, the DUT may be used as a reference subject to acceptable performance. Performance of the reference scale is to be determined before and after development of the product test load using known standards and the appropriate standard test procedures (STPs).

As there may be significant costs in terms of personnel and equipment required to conduct these inspections, they must be well planned and organized before proceeding. Before going to the site to perform the tests, the inspector must ensure the following:

- Sufficient and suitable quantity and type of material to complete a product test is readily available and suitable means to store, protect, move and dispose of the test product have been identified and arranged for.

- A suitable and inspected reference scale is accessible to either preweigh the test product before it is measured by the device to be tested, or to weigh the received product after it has been measured by the device. If the reference scale is not in the immediate vicinity of the DUT when using bulk commodities to develop a product test load, steps must be taken to ensure that the weight of the vehicle transporting the load does not change between net and gross weighings.

- All other testing equipment, appropriate number and type of local standards (see bulletin M-05), suitable test product and equipment to move test product between the DUT and the reference scale must be readily available. Any required personnel and operators must be available.

- The device is accessible so that all testing equipment can be brought in and used for the scale inspection. If product is to be loaded onto, or received from, the device in a non typical fashion, modifications to conventional operation may be required to facilitate inspection. Modifications shall be assessed to ensure that they do not significantly alter the operational characteristics of the DUT. Modifications between the device and the custody transfer point must not normally be permitted.

The inspector must, in advance, become familiar with the DUT, the reference scale and all other equipment and instrumentation that may be required to complete the test. The characteristics of

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the device, its operation and installation as well as the intended use are some of the elements that must be known by the inspector prior to testing. In the case of a continuous totalizing weighing system, large amounts of product may be required and arrangements must be made to remove the product after use. It is recommended that the inspector follow the product delivery path from loading to discharge to identify any possible areas of concern (product diversion, spillage or other loss).

Product test load

Product test loads may be developed before or after being measured by the DUT. The installation specifics determine which procedure is most appropriate. In each case, the basic procedure remains the same. It is extremely important to ensure that the entire product test load is measured by the DUT and none is lost to spillage or diversion. Although less common, it is also imperative to ensure that additional material is not introduced at any point during the testing.

Reference scale

The weight of the product test load will be obtained statically on a reference scale that has been demonstrated to perform accurately within the required limits of error. The reference scale must be tested using the Specifications Relating to Non-automatic Weighing Devices and suitable test standards. If an error is identified, the reference scale should be calibrated before it is used to establish product test loads. If calibration is not possible, or an error remains after calibration, this error must be considered in the development of the product test load.

The test load may be weighed on any suitable reference scale. Typically a bulk hopper, vehicle or rail scale is used for bulk commodities. Accessibility and performance will be the determining factors in selecting a suitable reference scale.

Any inherent error in the reference scale must be identified, documented and accounted for in the development of the product test load. Uncertainty in the test load due to the reference scale must be determined and accounted for.

Repeatability errors in the reference scale must be identified and accounted for in the development of the product test load. When using multiple drafts to establish the product test load, care must be taken to ensure that each weighing is performed in approximately the same location on the reference scale. This will reduce uncertainties due to eccentricity errors in the reference scale.

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Procedure

Develop product test load (bulk commodity)

Bulk commodities are those intended to be weighed by a totalizing weighing system. The total weight for each product test load will be determined either through a single weighing or, where the desired test load size is larger than the capacity of the reference scale, by accumulating multiple weighings. Product test loads may be weighed directly (net weight) or may have to be weighed in a suitable transport vehicle (gross weight). The procedures are slightly different in each case.

Selecting the scale used to create the test loads

1. Determine required product test load size using the appropriate STP for the DUT.

Testing the scale used to create the test loads

1. Inspect the reference scale using the appropriate STP and standards. For a larger capacity reference scale, standards may not be available to the maximum capacity. Strain or substitution testing will then be required to assess reference scale performance.

   a. Calibrate the reference scale as required. Every attempt should be made to eliminate all errors from the reference scale before proceeding. The reference scale must be linear throughout the weighing range.

   b. Note and record any actual error remaining in the reference scale[1] at the intended weighing range(s).

   The error ratio may be calculated as the actual value of the standards divided by the indicated value ($\bar{x}$) of the load. This ratio must be used to correct subsequent reference scale indications during test load development.

   $$Error\ ratio = actual\ \div indicated$$

   Alternately, the actual error may be calculated. The actual error is equal to the difference between the actual value of standards applied and the indicated value. This can be calculated as a percent of applied load:

   $$Percent\ error\ (Err\%) = \ [(indicated - actual) \div actual] \times 100$$

   c. Determine the error in the reference scale at the required weighing capacity. If standards capable of reaching the required capacity are not available, then the error at the required capacity must be estimated from the error identified with

[1] All identifiable errors must be accounted for in the total product test load value. This includes errors that are within the allowable LOE for the REF.

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standards applied. If the error in the reference scale is not linear, then the device should not be used to develop test loads. The error may be estimated using:

$$Error = (indicated \times error\ with\ standards) \div standards$$

Example: If an error of 10 kg is identified with 10 000 kg of standards on the reference scale, then the error at 100 000 kg test load is assumed to be 100 kg. This assumes performance of the reference scale is linear:

$$Error = (100\,000\ kg \times 10\ kg) \div 10\,000\ kg = 100\ kg$$

2. Calculate the uncertainty of the results. Note and record the repeatability error in the reference scale at the intended weighing range (gross and net) for between four and eight weighings ($4 \le n \le 8$). In the case of a vehicle scale, it is important to park the vehicle at approximately the same location for each weighing. Break point testing may be used if required to reduce the overall uncertainty.[2]

   a. If no repeatability error is evident, then uncertainty is equal to d_{REF}. $u = d_{REF}$

   b. If a repeatability error is evident, then uncertainty is found by the following:

   i. If the number of weighings is six or more, then total uncertainty for the test load is equal to the sample standard deviation of the results obtained from the repeatability testing:

$$u = s = \sqrt{\left[\left(\sum_{i=1}^{n}(\bar{x} - x_i)^2\right) \div (n-1)\right]}$$

   ii. If the number of weighings is less than six, then total uncertainty for the test load is equal to one half of the maximum displayed value (max) minus the minimum displayed value (min) as obtained during repeatability testing:

$$u = |\max - min| \div 2$$

Development of the test loads

1. Develop product test load. Apply product test load to the reference scale in approximately the same location as the test standards and strain or substitution load that were applied.

   a. In the case of a vehicle scale, it is important to park the vehicle at approximately the same location for each weighing. Any remaining eccentricity uncertainty will be captured in the calculations for repeatability uncertainty.

[2] If break points are used to simulate a smaller d_{REF} value, then this new value shall be used as the d_{REF} for the purposes of calculating uncertainties.

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b. When using a hopper or tank scale, or other scale with no discernible eccentricity error, the location where the load is applied is irrelevant.

c. Note and record d_{REF}. For a multi-interval device, record d_{REF} for each weighing.

2. Calculate total product test load value and uncertainty. For each weighing (*i*):

a. Note and record the indicated net product test load weight for each weighing (*i*) while adjusting the indicated weight to correct for any actual error in the reference scale as previously identified. If there is no actual error in the reference scale, then, $NetTL_i = Net_i$.

$$NetTL_i = Net_i \times error\ ratio$$

Or

$$NetTL_i = Net_i \times (Err_i\%) \div 100$$

b. If the net load is developed by the gross and tare weight, the net load must be calculated as gross weight minus tare weight. Any error in the reference scale must be accounted for at both the gross and tare loads. The actual tare weight must be determined for each gross weighing. Stored, marked or estimated tare weight values must not be used.

$$Net_i = Gross_i - Tare_i$$

Formula with error correction:

$$NetTL_i = (Gross_i \times error\ ratio) - (Tare_i \times error\ ratio)$$

Or

$$NetTL_i = [Gross_i \times (Err_i\ \%) \div 100] - [Tare_i \times (Err_i\ \%) \div 100]$$

Where:

$NetTL_i$ = Test load for weighing i

$Err\%$ is specific to each applicable load (gross, tare or net) on the reference scale.

c. Repeat the above steps as many times as necessary to develop a suitable test load. Sum each partial test load ($NetTL_i$) to arrive at the total test load.

$$Total\ Test\ Load = NetTL_1 + NetTL_2 + \cdots + NetTL_i$$

d. Calculate the total uncertainty. Individual uncertainties were calculated above.

i. If the net load is developed by the gross and tare weight, the total uncertainty for each net load must include uncertainties for each of the two

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weighings (gross and tare) and is calculated using the root sum square of the uncertainties:

$$u_{Net} = \sqrt{(u_{Gross})^2 + (u_{Tare})^2}$$

Where:
u_{Net} = uncertainty for net load
u_{Gross} = uncertainty for gross weighing
u_{Tare} = uncertainty for tare weighing

ii. Sum all net load uncertainties and multiply by the square root of the number of net loads (*n*) to find the total test load uncertainty. Do not count each gross and tare load, but rather, only the number of net loads to find *n*:

$$u_{Total} = \left(\sum (u_{Net})\right) \times \sqrt{n}$$

iii. Calculate expanded uncertainty for the total test load. Use a confidence factor (*k*) of 2 for a 95% confidence interval:

$$u_{Exp} = \left(\sum (u_{Net})\right) \times k$$

3. Compare total uncertainty to the limit of error (LOE) applicable to the DUT. If the total expanded (u_{Exp}) uncertainty exceeds ⅓ of the LOE applicable to the DUT, then the product test load is unsuitable and a new suitable product test load must be developed.

Note: If break points were used to simulate a smaller d_{REF} value, then this new value shall be used as the d_{REF} for purposes of calculating uncertainties.

If a product test load is found to be unsuitable due to uncertainties which exceed ⅓ of the LOE applicable to the DUT, there are several methods available to create a more suitable product test load.

- A better reference scale may be required:
  - A reference scale with a smaller *d* value will reduce the total uncertainty for each weighing.
  - A reference scale with a smaller repeatability error will reduce the total uncertainty for each weighing.
- Break points[3] may be used (if appropriate) during the development of the product test load to simulate a reference scale with a smaller *d* value.

[3] See Field Inspection Manual, Inspection Preparation, Appendix III for the appropriate procedure to use break points to simulate a smaller division or interval size.

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- Reducing the number of weighings needed to develop the product test load will reduce the overall uncertainty.
- Increasing the product test load size may increase the applicable DUT LOE. This may be sufficient to meet the ⅓ LOE requirement.

Load established before measurement by the device under test

Once a product test load has been established, it must be protected. Material which forms the product test load must be fully accounted for to ensure that the entire load is measured by the DUT. In addition, it is imperative that no additional product be introduced during the test.

Load established after measurement by the device under test

In those cases where the weight of the product test load is established after it is measured by the DUT. It is important to ensure that all the product is captured and accounted for. This can sometimes be difficult, as the amount of test product may exceed the capacity of a single truck or rail car. If product is lost, the test run must be rejected. It is relatively easy to lose product, especially on long conveyor runs. The entire system should be inspected before and after use to ensure that no product has been lost.

Develop product test load (individual commodity)

Individual commodities are those intended to be weighed over a discrete weighing system where each weight must be determined accurately. These are typically referred to as automatic catch weight devices. Product test loads are typically weighed as discrete loads as well and are not calculated based on the gross and tare weight. (Note: The gross load may include a stored tare weight that is addressed by the weighing system. The tare value is not required for testing the device.) Since these loads tend to be smaller, it is assumed that a suitable reference scale and standard weights capable of reaching the capacity of the device will be available. For this reason, this procedure is somewhat simplified over the previous bulk commodity procedure. If this is not the case, the bulk commodity procedure may be used instead.

Selecting the scale used to create the test loads

1. The use of a separate non-automatic reference scale is the preferred method of creating test loads. The actual scale interval (*d*) of the reference scale must be less than, or equal to, the actual scale interval of the DUT.

   $$d_{REF} \leq d_{DUT}$$

2. Subject to performance criteria, the DUT may be used in static mode if a suitable reference scale is not available.

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Testing the scale used to create the test loads

1. If the DUT is used to create the test loads, it must have been inspected and verified in static mode. If a separate reference scale is used to create the test loads, then it must also pass static testing using all appropriate STPs for the device.

2. Place standards equal to the desired test load weight on the reference scale. Remove and repeat eight times[4] (n = 8), recording the results each time, preferably to a resolution of at least 0.1 d_{DUT}.

    a. If the DUT will be used for weighing articles within a narrow band of weight values (i.e. deviation ≤ approximately ±5%), then the measurement error of the reference scale may be determined once at this load.

    b. If the DUT will be used for weighing articles with significantly varying weight values, then the measurement error of the reference scale must be determined at the largest weight.

    c. To minimize repeatability errors due to eccentricity, standards and test loads should be placed on approximately the same area of the load receiving element.

    d. The weight indication should be recorded to a resolution of at least 0.1 d_{DUT}. If d_{REF} is small enough, the weight indication may be read directly. If d_{REF} is too large, then break points must be used to determine the weight indication.

Note: Regardless of whether the DUT or a separate reference scale is used to create the test loads, for the scale to be considered suitable for creating test loads, the expanded uncertainty due to d_{REF} and the repeatability of the eight weighings must be within ⅓ of the LOE applicable to the DUT for the smallest test load to be prepared (see step 5 of the procedure for the development of the test loads).

3. Calculate the average ($\bar{x}$) of the eight weighings as determined above.

$$\bar{x} = \left(\sum_{i=1}^{n} (x_i) \right) \div n$$

4. The error ratio is equal to the actual value of the standard divided by the average of the indicated values ($\bar{x}$). This ratio must be used to correct subsequent reference scale indications during test load development.

$$error\ ratio\ = actual\ \div indicated$$

Alternately, if the actual product weight is known and consistent, the actual error may be calculated as an absolute value:

[4] Other values may be acceptable. Consult your regional gravimetric specialist for more details.

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$$absolute\ error\ =\ (indicated - actual)$$

Development of the test loads

1. Determine the total number of individual test loads required using the appropriate STP for the DUT.

2. Weigh each of the test loads (*i*) on the reference scale. Measurements must be taken to 0.1 d_{DUT} using small error weights if necessary. Record the results (TL_i).

3. Adjust indicated test load weight (TL_i) to include any measurement error as determined above. This new value will be the adjusted test load (ATL_i).

   $$ATL_i =\ TL_i\ \times error\ ratio$$
   Or
   $$ATL_i =\ TL_i + absolute\ error$$

4. Determine the uncertainty for each of the adjusted test loads (ATL_i):

   a. If the value of d_{REF} is at least 10 times smaller than d_{DUT} or the applicable DUT LOE for all test loads, then the uncertainty ($u_{d_{REF}}$) due to the value of d_{REF} may be considered insignificant. In this case, the uncertainty due to the value of d_{REF} is equal to zero. $(u_{d_{REF}} = 0)$. Proceed to step 4.b.

      If the value of d_{REF} is larger than noted in the previous paragraph, then the uncertainty $(u_{d_{REF}})$, due to the value of d_{REF}, must be considered. In this case the uncertainty due to the value of d_{REF} is equal to d_{REF} $(u_{d_{REF}} = d_{REF})$. Proceed to step 4.b.

   b. The uncertainty due to the repeatability ($u_{Repeatability}$) for the test load is ⅓ of the maximum displayed value (max) minus the minimum displayed value (min) when comparing the eight weighings recorded during repeatability testing of the reference scale:

      $u_{Repeatability} = |\max - min| \div 3$, Proceed to step 5.

5. The total combined uncertainty is the sum of the value determined in step 4.a. and the value determined in step 4.b.

   $$u_{Combined} =\ u_{d_{REF}} +\ u_{Repeatability}$$

   To ensure the required confidence level, multiply the combined uncertainty value obtained above by a confidence factor of two (*k* = 2) to find the expanded uncertainty.

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$$u_{Exp} = u_{Combined} \times k$$

6. Compare the total expanded uncertainty obtained in step 5 to the LOE applicable to the DUT for the test load. If the total expanded uncertainty does not exceed ⅓ of the LOE applicable to the DUT, the range of acceptable dynamic weights for the test load can be determined as outlined in step 7. If the total expanded uncertainty exceeds ⅓ the LOE applicable to the DUT, then the product test load is unsuitable and a new suitable product test load must be developed.

   Note: If a product test load is found to be unsuitable due to an expanded uncertainty which exceeds ⅓ of the LOE applicable to the DUT, there are several methods available to create a more suitable product test load.

   - A better reference scale may be required:
     - A reference scale with a smaller *d* value will reduce the total uncertainty for each weighing.
     - A reference scale with a smaller repeatability error will reduce the total uncertainty for each weighing.

   - Break points[5] may be used (if appropriate) during the development of the product test load to simulate a reference scale with a smaller *d* value.

   - Increasing the product test load size may increase the applicable DUT LOE. This may be sufficient to meet the ⅓ LOE requirement.

7. To facilitate the testing of the DUT, determine the range of acceptable dynamic weights for each test load. These values are based on the applicable LOE from section 176 or 177 of the *Weights and Measures Regulations* as appropriate for each of the test loads. For each test load:

   a. $The\ acceptable\ upper\ value\ indicated\ by\ the\ DUT\ (dynamically) for\ a\ test\ load = adjusted\ test\ load\ (ATL_n) + \left[LOE(R176/R177) + {}^{1}\!/_{2}\, d_{DUT}\right]$

   b. $The\ acceptable\ lower\ value\ indicated\ by\ the\ DUT\ (dynamically) for\ a\ test\ load = adjusted\ test\ load\ (ATL_n) - \left[LOE(R176/R177) + {}^{1}\!/_{2}\, d_{DUT}\right]$

8. Complete the above steps for each of the product test loads.

[5] See Field Inspection Manual, Inspection Preparation, Appendix III, for the appropriate procedure to use break points to simulate a smaller division or interval size.

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Interpretation of results

For bulk commodities, the reference test load as determined on the reference scale is considered to be the known test load for the purposes of assessing performance of the DUT.

In the case of individual products, each product test load must fall between the acceptable upper value and lower value as determined in the procedure.

Revision

Revision 1 - Editorial changes and extensive modifications to the Product Test Load Development procedure for individual commodities.