December 15, 2015

Hopper Scales - *Selecting the Appropriate Device*

Byline: John Barton

The NIST Office of Weights and Measures (OWM) over time has received a number of inquiries regarding the suitability, use, and testing of hopper-type scales. The nature of those inquiries provides some indication that there is a lack of detailed information regarding the assessment of whether these devices are appropriate for the intended application.

A number of inquiries concerned the use of hopper scales as reference scales used in testing automatic weighing systems such as belt-conveyor scales. These particular inquiries have raised questions related to the operation, design, and configuration of these types of scales. This article has been written to address those questions specifically related to electronic/digital indicating hopper scales and to provide recommendations for the testing of hopper scales.

General

"Hopper" is the general term used to describe a containment vessel whose design is influenced by the physical properties of the materials that they are intended to hold. These types of weighing devices are typically installed where the weight of "free-flowing" materials contained in the hopper will be determined. The types of materials typically weighed in these scales are not readily contained on open, flat surfaces and must be confined within a vessel when the weight is determined to prevent any loss of the material. Companies that produce or process materials such as stone aggregates, coal, metal ore, scrapped or recycled materials, liquid or granular chemical products; and agricultural grains are some examples of various operations where these types of scales may be found. Capacities of these scales vary greatly and range from under 50 kg (100 lb) to many thousands of kilograms.

While the design of the hopper can vary according to the needs of the operation with which it is associated, the shape of the load receiving element is generally a funnel-type shape that allows materials that are loaded into the hopper to typically be discharged from the bottom of the hopper. The customary inward slope of the sides towards the bottom of the hopper facilitates a complete discharge of product once its quantity has been determined.

This type of design does not typically provide structural surfaces from which test weights can easily be placed or suspended, and this can be a major consideration during the testing or calibration of hopper scales. In many cases where these devices are used (particularly in large capacity weighing applications), the application of test weights can be problematic. Often, these devices will not accommodate the placement of test weight in amounts that approach the actual capacity of the device in a safe manner. For this reason, in cases involving large capacity hopper scales, it may be necessary to use either a substitution or strain-load method of testing, or a combination of these tests when performing an official examination or during calibration of the device.

Selection of an appropriate device

The considerations for selecting a hopper scale for a particular use are much the same as for other weighing devices. The material being weighed, the typical draft size, accuracy classification, the scale's resolution, and the ability to interface with associated equipment are some of the features that must be considered when making a determination for an appropriate device.

Several requirements found in NIST Handbook 44 (HB 44), "Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices," will aid in the selection of a suitable device for various applications. One such requirement is a general guideline provided in NIST HB 44, Section 2.20. Scales Code paragraph UR.1. Selection Requirements shown below.

> **UR.1. Selection Requirements.** – Equipment shall be suitable for the service in which it is used with respect to elements of its design, including but not limited to, its capacity, number of scale divisions, value of the scale division or verification scale division, minimum capacity, and computing capability.[1]
>
> [1] Purchasers and users of scales such as railway track, hopper, and vehicle scales should be aware of possible additional requirements for the design and installation of such devices.
> (Footnote Added 1995)

This generic statement lists some examples of the concerns that need to be taken into account in order to ensure that a scale is suitable for the intended purpose. The footnote included with this requirement also indicates that specific types of scales may have additional requirements associated with their design and installation.

Scale capacity

A fundamental feature to consider in selecting a scale is the nominal capacity of the scale needed for the particular application. The parameters for this feature should be relatively easy to determine. The capacity will depend on the value of the initial "deadload" (the weight of the structural elements that will support the applied loads) as well as the maximum load expected to be weighed on the device. Manufacturers will typically design a scale with a capacity that will incorporate an extended weighing capability beyond the expected maximum load. This additional capability is intended to prevent potential damage from overloading and to withstand the effects of "shock" loading.

Scale division size

In addition to the scale's capacity, it is necessary to determine an appropriate value for the scale division. The suitability of the scale division is somewhat of a practical matter, as it is often based on the monetary value of the commodity being weighed. Recognizing that devices constructed by humans will inherently contain some error, and allowing that those weighing devices are permitted some variation from the true weight value when indicating a weight, the monetary value of a scale division must be considered.

For example, an error of one scale division on a scale with a division size of 0.5 kg will represent a monetary error of $5.00 for a commodity priced at $10.00/kg. However, for a commodity priced at $0.10/kg, that error represents a monetary value of only $0.05. As demonstrated here, variation of a single scale division could have a large effect on a transaction and, therefore, the size of the scale division is an important consideration.

For those scales manufactured prior to January 1986 and not marked with an accuracy class, NIST HB 44, 2.20. Scales Code, Table 7b. Applicable to Devices not Marked with a Class Designation contains guidance on the selection of a maximum division size for a scale, based on the scale's design, or intended use.

Table 7b.
Applicable to Devices not Marked with a Class Designation

Scale Type or Design	Maximum Value of d
Retail Food Scales, 50 lb capacity and less	1 oz
Animal Scales	1 lb
Grain Hopper Scales Capacity up to and including 50 000 lb Capacity over 50 000 lb	 10 lb (not greater than 0.05 % of capacity) 20 lb
Crane Scales	not greater than 0.2 % of capacity
Vehicle and Axle-Load Scales Used in Combination Capacity up to and including 200 000 lb Capacity over 200 000 lb	 20 lb 50 lb
Railway Track Scales With weighbeam Automatic indicating	 20 lb 100 lb
Scales with capacities greater than 500 lb except otherwise specified	0.1 % capacity (but not greater than 50 lb)
Wheel-Load Weighers	0.25 % capacity (but not greater than 50 lb)
Note: For scales not specified in this table, G-UR.1.1. and UR.1. apply. (Added 1985) (Amended 1989)	

As can be seen in Table 7b, hopper scales that are not marked with an accuracy class and which are used for weighing grain are permitted a maximum scale division size of 10 lb for capacities up to 50,000 lb. For those scales whose capacity exceeds 50 000 lb the maximum value of the scale division permitted is 20 lb.

For hopper scales used to weigh other materials, the maximum scale division size is found in Table 7b, listed under "Scales with capacities greater than 500 lb except where otherwise specified." The value listed for that category of device is 0.1 % of scale capacity (but not greater than 50 lb).

Scale resolution

The features of a scale that have already been considered (scale capacity and scale division size) will determine the scale's resolution. The resolution of a scale can be described by the ratio between the total number of scale divisions and the weighing range or capacity of the scale. The total number of divisions (n) within a scale's range of operation can be found using the following formula:

n = scale capacity ÷ scale division size (d)

A scale whose capacity is 100 kg and division size is 0.1 kg has 1000 divisions (or 1000 d).

The resolution of a scale is an important consideration when it is recognized that the actual gravitational force sensed by the weighing elements of a scale when a load is applied may not exactly correspond to any fixed increment the device has been programmed to display. The applied load to the scale may have an actual weight value that does not correspond *exactly* to a value that can be displayed due to the limited capability of the device. In other words, the limited number of increments that the scale is programmed to display may be insufficient to represent the exact weight of a load placed on the scale. During the process of determining and then displaying a value for the load applied, a digital indicating device will follow a rounding procedure to select what scale increment is closest to the actual weight applied.

For example, a scale that is programmed to indicate weight values in increments (scale divisions) of 1 kg will be incapable of representing the exact weight value of a load weighing 100.7 kg. To display an indication of weight for a load of 100.7 kg, this scale must round the value (either up or down) to a whole number value. The scale must "decide" whether to indicate a value of 100 kg or 101 kg. In this case, according to the NIST HB 44 rules of rounding, it would be expected that the scale would display a weight indication of 101 kg for that load.

As the number of scale divisions increase, so does the ability of the scale to more precisely indicate a true weight value for any load placed on the scale. This ability is dependent upon the functioning of the scale's rounding procedure, where only a *finite* number of divisions programmed into the scale are available to accurately display an *infinite* number of possible actual weight values. Just as the clarity of a photograph improves with an increase in the number of pixels utilized by a camera, the ability to represent a weight value with precision increases proportionally with the scale's resolution.

Accuracy Class

Another consideration for the suitability of a scale is its accuracy class rating. The accuracy class designation declared by the manufacturer provides an indication of the level of precision that can be expected from the scale. A reference from NIST HB 44 related to a device's suitability based on this accuracy classification is found in Section 2.20. Scales Code, paragraph UR.1.1. General. The second paragraph of this requirement, under (b) refers to Table 7b as mentioned previously. However, the first part of this paragraph refers to Table 7a and provides general guidelines for the type of application that is appropriate for scales marked with accuracy classifications.

UR.1.1. General.

(a) For devices marked with a class designation, the typical class or type of device for particular weighing applications is shown in Table 7a. Typical Class or Type of Device for Weighing Applications.

(b) For devices not marked with a class designation, Table 7b. Applicable to Devices not Marked with a Class Designation applies.

Table 7a.
Typical Class or Type of Device for Weighing Applications

Class	Weighing Application or Scale Type
I	Precision laboratory weighing
II	Laboratory weighing, precious metals and gem weighing, grain test scales
III	All commercial weighing not otherwise specified, grain test scales, retail precious metals and semi-precious gem weighing, animal scales, postal scales, vehicle on-board weighing systems with a capacity less than or equal to 30 000 lb, and scales used to determine laundry charges
III L	Vehicle scales, vehicle on-board weighing systems with a capacity greater than 30 000 lb, axle-load scales, livestock scales, railway track scales, crane scales, and hopper (other than grain hopper) scales
IIII	Wheel-load weighers and portable axle-load weighers used for highway weight enforcement
Note: A scale with a higher accuracy class than that specified as "typical" may be used.	

(Amended 1985, 1986, 1987, 1988, 1992, 1995, and 2012)

Scales that are marked with an accuracy classification must comply with the parameters set in NIST HB 44 under paragraph S.5.2. Parameters for Accuracy Class and the associated Table 3. Parameters for Accuracy Classes as shown below.

S.5.2. Parameters for Accuracy Class. *– The accuracy class of a weighing device is designated by the manufacturer and shall comply with parameters shown in Table 3.*
[Nonretroactive as of January 1, 1986]

Table 3. provides the maximum and minimum number of scale divisions (n_{max}) allowed for each accuracy classification. As mentioned previously, this number of scale divisions is determined by dividing the nominal capacity of the scale by the scale division.

Table 3.
Parameters for Accuracy Classes

Class	*Value of the Verification Scale Division (d or e[1])*	*Number of Scale[4] Divisions (n)*	
		Minimum	*Maximum*
SI Units			
I	*equal to or greater than 1 mg*	*50 000*	*--*
II	*1 to 50 mg, inclusive*	*100*	*100 000*
	equal to or greater than 100 mg	*5 000*	*100 000*
III[2,5]	*0.1 to 2 g, inclusive*	*100*	*10 000*
	equal to or greater than 5 g	*500*	*10 000*
III L[3]	*equal to or greater than 2 kg*	*2 000*	*10 000*
IIII	*equal to or greater than 5 g*	*100*	*1 200*
U.S. Customary Units			
III[5]	*0.0002 lb to 0.005 lb, inclusive*	*100*	*10 000*
	0.005 oz to 0.125 oz, inclusive	*100*	*10 000*
	equal to or greater than 0.01 lb	*500*	*10 000*
	equal to or greater than 0.25 oz	*500*	*10 000*
III L[3]	*equal to or greater than 5 lb*	*2 000*	*10 000*
IIII	*greater than 0.01 lb*	*100*	*1 200*
	greater than 0.25 oz	*100*	*1 200*

[1] *For Class I and II devices equipped with auxiliary reading means (i.e., a rider, a vernier, or a least significant decimal differentiated by size, shape, or color), the value of the verification scale division "e" is the value of the scale division immediately preceding the auxiliary means.*

[2] *A Class III scale marked "For prescription weighing only" may have a verification scale division (e) not less than 0.01 g.*

(Added 1986) (Amended 2003)

[3] *The value of a scale division for crane and hopper (other than grain hopper) scales shall be not less than 0.2 kg (0.5 lb). The minimum number of scale divisions shall be not less than 1000.*

[4] *On a multiple range or multi-interval scale, the number of divisions for each range independently shall not exceed the maximum specified for the accuracy class. The number of scale divisions, n, for each weighing range is determined by dividing the scale capacity for each range by the verification scale division, e, for each range. On a scale system with multiple load-receiving elements and multiple indications, each element considered shall not independently exceed the maximum specified for the accuracy class. If the system has a summing indicator, the n_{max} for the summed indication shall not exceed the maximum specified for the accuracy class.*

(Added 1997)

[5] *The minimum number of scale divisions for a Class III Hopper Scale used for weighing grain shall be 2000.*)

[*Nonretroactive as of January 1, 1986*]

(Added 2004) (Amended 1986, 1987, 1997, 1998, 1999, 2003, and 2004)

It is important not to overlook the footnotes included in Table 3, the last of which makes the distinction between Class III hopper scales used to weigh grain and other scales marked as "Class III." Class III hopper scales used to weigh grain are not permitted to have less than 2000 scale divisions, whereas other types of Class III scales may have as few as 100 or 500 depending on the value of the scale division. Scales used for weighing grain are expected to perform to a higher standard and provide more precise weighments. This higher standard for scale resolution is also found in NIST HB 44, 2.20. Scales Code, paragraph UR.1.2. Grain Hopper Scales as shown below.

> **UR.1.2. Grain Hopper Scales.** – Hopper scales manufactured as of January 1, 1986, that are used to weigh grain shall be Class III and have a minimum of 2000 scale divisions.
> (Amended 2003)

At the time of the 1986 revision of the NIST HB 44 Scales Code, existing technology was used as a basis to determine where to set limitations for the maximum and minimum number of divisions required under the various accuracy classifications. Just as is the practice today, manufacturers at the time designed devices based on the needs and demands of their customers. Most of those devices were designed with configurations that included a range of 2000 – 6000 divisions. The range of the number of divisions found in today's current market has remained consistent with that of three decades ago.

The weighing demands in the majority of industrial settings found today can generally be met using Class III or IIIL scales, both of which have a maximum limitation of 10 000 divisions. If the need for a weighing device with more than 10 000 divisions exists, a scale of a higher accuracy class can be used. Class II scales have a limit of 100 000 divisions, and Class I scales have no limitation on the number of divisions. Devices designated as accuracy classifications I and II typically represent high precision devices such as laboratory balances, analytical scales, and devices used for weighing precious metals and gems.

Minimum load

An additional NIST Handbook 44 requirement pertaining to suitability worth noting is paragraph UR.3.1. Recommended Minimum Load. The excerpt of this requirement, shown below with the associated Table 8. Recommended Minimum Load, provides a guideline for the recommended minimum loads to be weighed on a scale.

> **UR.3.1. Recommended Minimum Load.** – A recommended minimum load is specified in Table 8 since the use of a device to weigh light loads is likely to result in relatively large errors.

Table 8. Recommended Minimum Load		
Class	**Value of Scale Division (d or e*)**	**Recommended Minimum Load (d or e*)**
I	equal to or greater than 0.001 g	100
II	0.001 g to 0.05 g, inclusive	20
	equal to or greater than 0.1 g	50
III	All**	20
III L	All	50
IIII	All	10

*For Class I and II devices equipped with auxiliary reading means (i.e., a rider, a vernier, or a least significant decimal differentiated by size, shape or color), the value of the verification scale division "e" is the value of the scale division immediately preceding the auxiliary means. For Class III and IIII devices the value of "e" is specified by the manufacturer as marked on the device; "e" must be less than or equal to "d."

**A minimum load of 10 d is recommended for a weight classifier marked in accordance with a statement identifying its use for special applications.

(Amended 1990)

Determining the weight of a load placed on a scale using only relatively few of the scale divisions within a scale's range has the effect of increasing the potential error present (as a percentage of the total load) in the measurement.

This can be illustrated through the following example where two different loads are weighed on the same scale. Provided the scale has been verified as accurate (i.e., within allowable tolerances), the potential for error in either example can reasonably be expected to be as much as (and possibly greater than) one-half of one division. This amount can be attributed to the rounding process discussed previously. Any weight sensed by the scale as a value that falls between two adjacent divisions will be displayed as either of the adjacent divisions, due to the rounding of the displayed increments by the indicating element.

Scale capacity: 2000 kg
Scale division size: 0.5 kg

Load #1: 500 kg

In this first example, if the display of 500 kg by the scale has a potential error of one-half of the division size, that error represents 0.05% of the load weighed (0.25 kg ÷ 500 kg).

Load #2: 50 kg:

In this second example, the potential error is much more significant when compared to the value of the load placed on the scale. The display of 50 kg by the scale again has a potential error of 0.5 % (0.25 kg ÷ 50 kg); this is ten times the value for that of load #1.

The relatively large errors encountered when using a scale to weigh small loads can be mitigated by following the recommendations for minimum loads as stated above in paragraph UR.3.1. Recommended Minimum Load.

Minimum test loads and testing

NIST HB 44 addresses the amount of mass standards (test weights) that will be applied to the scale during an examination of a scale. According to these Scales Code requirements, minimum amounts for test loads must be used in order to certify that the scale is capable of meeting established performance criteria. It is important to consider these minimum values when selecting a weighing device and during the proper installation and set-up of that device.

It should be recognized that a scale which will be tested as a commercial weighing device, should be installed in such a manner that will accommodate a proper testing procedure. As mentioned previously, the typical design of the weighing elements in this type of device can create challenges when test weights must be applied during testing and calibration. Ideally, provisions for placing sufficient amounts of test weights on, or suspending them from the weighing elements will be made when the device is installed.

The requirements contained in NIST HB 44, Scales Code pertaining to the minimum amount of test weights and test loads are found in paragraph N.3. Minimum Test Weights and Test Loads and the associated Table 4. Minimum Test Weights and Test Loads.

N.3. Minimum Test Weights and Test Loads. – The minimum test weights and test loads for in-service tests (except railway track scales) are shown in Table 4. (Also see Footnote 2 in Table 4. Minimum Test Weights and Test Loads.)

(Added 1984) (Amended 1988)

Table 4.
Minimum Test Weights and Test Loads1

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.

When followed during the testing of the scale, the minimum test load requirements will provide a high degree of confidence that the test performed will be an accurate reflection of the scale's capabilities. A proper test will include the application of test loads in increasing amounts throughout the range of the scale's weighing capacity to provide evidence that the scale will perform accurately when in operation. It is unfortunate that due to problems encountered when applying large amounts of test weights to the weighing elements of hopper-type scales, frequently, only the required minimum weight/loads will actually be applied.

In certain applications, it is not uncommon to find very large hopper scales used to weigh heavy, dense material. These larger hopper scales can be found in industries such as grain, mining, and quarry operations and have capacities of well over 50 000 kg.

One of the inquiries that OWM received involved a hopper scale with a reported capacity of 144 000 lb[1]. Considering the table above, it can be determined that the minimum amount of test weight required for this scale would be 18 000 lb. This same table also provides the value for the minimum test load to be applied during a test on this hopper scale as 36 000 lb.

It should not be difficult to appreciate that the minimum amount of test weight required is significant and the application of physical standards in this amount could present a problem when attempting to apply that amount of test weight to the load receiving element. Table 4. Minimum Test Weights and

[1] Although official NIST policy is to express quantitative values in SI units, the example referred to in this article was based on U.S. customary values as reported to NIST. Therefore, for the purpose of consistency and clarity in communication, U.S. customary values are being used in the context of that example.

Test Loads include several informative footnotes including the statement shown below that addresses this situation.

> [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.

A Case Study in Scale Selection

The particular inquiry mentioned above raised additional questions involving some of the main issues discussed in this article; not only with the suitability of a device's configuration, but also the importance of proper test practices.

The focus of the inquiry pertained primarily to the size of the minimum scale division permitted by NIST HB 44 for a hopper scale. The example provided in the inquiry was a large capacity hopper scale configured with a relatively large division size (50 lb) being used to load railway cars with bulk material. The inquirer questioned whether a smaller (20 lb) division size would be preferable and asked for clarification on whether or not this particular hopper scale would be capable of providing weighing results within accuracy limits allowed by NIST HB 44.

The details of the inquiry provided information which implied that two consecutive drafts from this scale would be needed to develop a sufficient load suitable for each railway car. Additionally, this scale was routinely tested and calibrated using only the NIST Handbook 44 required *minimum* amount of test weight necessary to certify the scale under the handbook requirements.

As mentioned earlier, NIST HB 44, Section 2.20. Scales Code, Table 4. Minimum Test Weights and Test Loads requires that a minimum of 12.5 % (or 5000 kg) of the device capacity be used as a minimum test weight. In this instance, 12.5 % of the scale's nominal capacity is equal to 18 000 lb. This 18 000 lb is the minimum *test weight* needed for an official test on this device and does not include the minimum *test load* of 25 % of device capacity (or 36 000 lb) also required as part of an official test.

NIST OWM's response also included references to support this interpretation including: NIST Handbook 44, Section 2.20., Table 3. Parameters for Accuracy Classes; and Tables 7a. Typical Class or Type of Device for Weighing Applications and 7b. Applicable to Devices not Marked with a Class Designation, which provide typical applications and division sizes for different classes of weighing devices.

This particular hopper-type scale (if marked with an accuracy class) would appropriately be identified with a "Class III L" accuracy classification. NIST HB 44 limits the maximum number of divisions for a Class III L device to 10 000 divisions. In that context and in compliance with this limitation, NIST OWM believes a division size of either 50 lb or 20 lb would be acceptable for the scale mentioned in this inquiry.

NIST received input from another outside source that presented an argument opposing the use of a 50 lb scale division for this hopper scale. The justification for this opposing point of view pointed to a comparison made between the two values of 18 000 lb (minimum test weight) and 50 lb (division size) as follows:

50 lb ÷ 18 000 lb = 0.0027 (or 0.27 %)

This particular response to the inquiry compared this ratio (0.27 %) to the value of 0.2 % which had traditionally been used as the maintenance tolerance during official testing of this type of scale prior to the revision of the NIST Handbook 44, 2.20. Scales Code. Because the resulting ratio between the minimum test load and the 50 lb scale division was larger than the value of the former tolerance, it was perceived by some to imply that the 50 lb division size was unacceptable for this application.

This value of 0.27 %, however, is merely an indication of one contributing factor to the potential uncertainty associated with the scale's indication of 18 000 lb of test load, and NIST OWM believes it should not be interpreted as a definitive statement of the scale's ability to perform accurately over its entire weighing range. Because this particular scale was being tested using only 18 000 lb of actual test weight, some who opposed the use of a 50 lb scale division attributed the 0.27 % ratio between these values as a reflection upon the scale's ability to accurately indicate the weight value of a typical load. This ratio also provided a cause for doubt for others who questioned whether performing an official test using the minimum test weight is a valid test procedure for a scale configured with 50 lb divisions.

While the ratio between the values of scale division size and required minimum test weight can provide an indication that a displayed weight value at this point may be subject to a relatively large amount of uncertainty, this ratio value should not be given greater significance by inferring the scale's configuration is unsuitable or the scale is inaccurate.

To explain further, consider a scale with a minimum division size of 20 lb where a test load of 100 lb is placed on the scale. Using the logic applied above by calculating a ratio between the scale division size and test weight applied, can a definitive statement be made that the accuracy of the scale is 20 %? Obviously the answer is no. If the scale at this point displays an indication of 100 lb, can it be stated without reservation that the scale is 100 % accurate? Again, the answer is no.

A conclusion that can be drawn from this comparison between test load and minimum division size is, in this instance, the use of an 18 000 lb test load is an insufficient load to properly assess a 144 000 lb capacity scale's accuracy due to the potential uncertainty in the measurement. The 18 000 lb of test weight in this case is a minimum test weight and further testing is needed to fully evaluate that scale's performance.

The hopper scale involved in this inquiry was reportedly used routinely to determine the value of loads closer to the 100 000 lb range. The testing of this hopper scale would have appropriately included substitution and strain-load tests to verify its performance in the range of draft sizes typically used. If this device had been tested using larger test loads closer to its capacity (or used capacity), then a comparison of the test weight applied and the scale division would promote a very different conclusion if the same logic is applied. The ratio between a scale division of 50 lb and a 100 000 test load would be 0.05 %.

Any assessment of this device's performance should be based on its ability to indicate a weight value that represents the actual value of the load placed on the weighing element. In other words, the scale must perform within the allowable error (i.e., tolerance). A change in the size of the minimum division from 50 lb to 20 lb will have an effect in this respect by decreasing the allowable maintenance tolerance for 18 000 lb of test weight from plus or minus 50 lb to plus or minus 40 lb. As this example illustrates, a change in division size, such as what has been suggested, can have significant effect on the resolution of the device but has only a minimal effect on establishing the scale's accuracy.

In summary, the inquiry referred to in this article illustrates the risk of using a limited set of criteria in determining the suitability of a weighing device rather than considering the many factors that are important in this determination. Multiple factors such as: design and construction of the hopper, accuracy (accuracy classification) required, scale capacity, scale division size, and what material is to be weighed are all crucial in the scale's ability to produce accurate weighing results.

Comments or questions about this article may be forwarded to:

John Barton
NIST OWM, Legal Metrology Devices Program
(301) 975-4002
john.barton@nist.gov