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The Equipment and Facilities Specifications Newsletter

An official copyrighted publication of the Equipment and Facilities Specifications Subcommittee of the National Officials Committee in its 20th year of publication

WELCOME TO NEW SUBSCRIBERS

This Newsletter is a semi-annual educational tool for Implement Inspectors, Technical Managers, interested Throws Officials, and certification chairs. Input and suggestions are always welcome. This copy is being sent to about 830 officials around the world. Welcome to our new subscribers this year:

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CHAIRMAN'S CORNER

There seems to be one problem that we keep facing as implement inspectors. Many times when we disqualify something, the coach (or the athlete) will state that the same implement passed at XYZ meet just two weeks ago or something along those lines. We have all heard this many times, but why does this happen?

One possible explanation is that the particular problem was not checked at that XYZ meet. This can happen for several reasons, but I suspect most of the problem is workload. We will quite often skip some checks because we don't have the time to do everything that needs to be done. At the NCAA D-1 outdoor meet this year we had over 200 javelins to check. With this many javelins it is hard to check everything. Luckily for us at that meet, we had time to do those javelins well since we didn't have a javelin competition early in the meet and athletes checked them in early. We also had a great new tool from UCS that made many of the checks quick and easy to do. Look for my review of this in the February newsletter.

Another possibility is that the weights and measures official didn't think that particular limit was that important and so didn't check it. How many times have you checked the diameter of the rod that forms the handle on the weight throw? Personally, it is not one that I tend to do. I eyeball the handle and as long as it looks solid and about a half inch in diameter, I will pass it. I do check the weld to make sure it is solid and secure as that is a safety issue.

The vexing one is weight. Please see a much more detailed discussion of this problem elsewhere in this newsletter. Some athletes want to have their implement (generally the shot or hammer) as close to the limit as possible. They will adjust the weight before coming to the big meet to make sure it is exactly at the limit. What they fail to understand is that the scale they used may not have been calibrated recently while the one at the meet may well have been. The rules state that scales need to be calibrated once a year. In my opinion any scale used at a national championship should be calibrated just before the meet. The scale used two weeks ago at XYZ meet may not have been calibrated either and a shot passed at that meet that should not have.

A similar problem comes with the 7.260 kg shot. Some athletes like those to be as large as possible and so purchase a 129 mm diameter shot. Sometimes the manufacturer's quality control is not the best and those shots are larger than the 130 mm limit. Another possible problem with those shots is the ring gauge itself. We need to know what the actual diameter of that gauge is. Some of them will be less than the 130 mm limit and therefore will disqualify a shot that is perfectly legal.

Another reason a hammer may pass at XYZ meet, but not one two weeks later is that some of the handles stretch. We had several at the national masters meet that stretched up to 2 mm during the meet. They were legal at 110 mm when the meet started, but measured 111 mm or 112 mm after the meet. Hammer throwers are used to changing wires as those stretch as well and will sometimes replace a handle due to weight concerns, but seldom due to a handle stretching. Those are not supposed to stretch.

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The point here is for each of us to make sure we don't cause problems for others along the line. Treat each meet as a "big deal" meet and make sure that all implements are legal in all respects. That will help the athletes as well since they seldom want to turn in an implement that won't pass inspection. On the whole we do a good job along those lines and the complaint mentioned above does not come up often at all.

I have received reports from various meets around the country this year and the percentage of disqualified implements is small. The summary of that is not yet available and I hope to have that done for 2010 by the February newsletter. I would love to get reports from as many meets as possible over the next year.

Anyone receiving this newsletter is welcome to help put it out by submitting articles. These articles need to relate to the subject of the committee. Any problems that come up may be sent to us as well. Keep us informed as to what is happening out there.

E&FSS ANNUAL CONVENTION MEETING

The subcommittee annual meeting will be held on Thursday, December 2, at 3 PM in Virginia Beach, VA.

RULE CHANGES AFFECTING EQUIPMENT OR FACILITIES

The **NFHS** press release concerning 2011 high school rules changes did not contain any equipment or facilities revisions. However, a point of emphasis regarding the discus cage guidelines is forthcoming.

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The following **NCAA** rules changes, that affect equipment & facilities, have been announced for 2011-2012:

Rule 1-1.7: The finish line painting scheme has been modified for assistance in camera alignment.

Rule 1-5.3: PV runway markings have been modified.

Rule 1-7.5: The requirements for the discus circle insert (to create a hammer circle) have been modified.

Rule 1-9.1: The discus/hammer cage design requirements have been clarified.

Rule 6-1.13a: The rule has been modified to remove the vaulting pole and jumping shoe from the list of implements.

Rule 6-10.1: Clarifies the definition of javelin "metal head."

Rule 8-2.1: XC course lengths are modified.

Rules 8-2.2, 8-2.3 & 8-3a: Multiple rule modifications regarding the layout and marking of XC courses.

Rule 10-2.3: The finish line painting scheme has been modified for assistance in camera alignment.

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The 2011 **USATF** proposed rules change package has been released. A summary of the proposed changes, as pertains to equipment and facilities, is contained below.

Item 46, Rule 169.5(a): Prohibits placement of blockage under the steeple chase water barrier.

Item 65, Rule 193.10: Redefines the 500 g mini-javelin, and creates a 600 g mini-javelin.

Item 66, Rule 195.4: Clarifies the throwing weight head specification, and brings it into WMA conformity.

Item 67, Rule 195.5: Modifies the throwing weight handle specification, and brings it into WMA conformity.

Item 68, Rule 195.6: Modifies the throwing weight connection specification.

Item 69, Rule 195.9: This rule is deleted; and Rule 196 is created to codify the ultraweight pentathlon implement and throwing area rules.

Item 72, Rule 203: Codifies the ultraweight pentathlon rules of competition.

Item 73, Rule 203 chart: Adjusts the ultraweight pentathlon table to reflect new implements for W75+ age group.

Item 74, Rule 221.5: Clarifies the indoor shot specs for Masters men and Youth boys.

Item 91, Rule 301: Adds the 300 g mini-javelin to the Sub-Bantam classification.

Item 94, Rule 302.4(a): Adds hurdle specifications for the Midget indoor classification.

Item 95, Rule 302.5(n): Changes the responsibility for performing Youth PV pole inspection.

Item 109, Rule 332.2(j): Codifies the Masters shuttle hurdle rules.

Item 112, Rule 332.3(g): Modifies the Masters women's superweight implements.

Item 115, Figures 14 & 15: Adds several hammer and throwing weight handle examples.

Item 116, #7, Rule 188.4: Corrects a note under the shot specification table.

Item 116, #10, Rule 203.3 table: Corrects the women's Open-49 implement requirements.

Item 116, #15, Rule book front cover: Corrects the hammer handle sketch.

EQUIPMENT CORNER

If you have any information on equipment that you have purchased or built to help with your weight and measures or technical managers' activities, please pass along the information. One of our goals is to disseminate this type of information.

Polanik Throwing Weight Swivel Key
Anyone who works on hammers knows that Polanik hammer swivels require a special tool to remove them (Polanik hammer swivel key, product code HK).

Polanik throwing weights require a larger key of the same design to remove their swivels. This larger key has not been available until now. Polanik has recently announced this new offering (product code TWK, http://polanik.eu/TWK_throwing_weight_swivel_key-631.html).

The throwing weight swivel key will be available from M-F Athletic in late September. Contact them at 800-556-7464 or e-mail mfathletic@mfathletic.com. The Order Item number is 5393 and will cost $32.95.

Throwing Weight Length Measurement Stand
The last newsletter discussed two makes of length measurement stands for the throwing weights. In particular, it was pointed out that setting the measurement gap for two models of stands (shown below) is somewhat difficult without specialized tools.

The editor has use of a digital inside caliper which makes this job much easier with accurate results, and will perform this adjustment free of charge for anyone that requires it. The owner must cover the shipping expenses in both directions. Please contact the editor at TF_ikstrums@comcast.net and specify which length is required (40.64 cm or 41.00 cm).

Additionally, the editor also can adjust the Gill measurement stand to better accuracy than is attainable by a tape measure, if that is desired.

Cleaning marks off implements (Part B)
The last newsletter described a comprehensive test to see which cleaners or solvents cleaned markings off implements the best. At issue was implements with too many certification markings on them, or previous markings that are too similar to the one(s) in use at a current meet.

Three types of markers were used: Sharpie, Elmers' Painters Paint Markers (water-based acrylic), and Krylon Short Cuts Paint Pens (oil-based enamel).

The test was conducted on fairly short notice; hence, only one day was given for the markings to dry before the cleaning operation. The surfaces tested were aluminum, plastic discus sides, and javelin.

A second phase of the test was performed this summer. Several types of implement surfaces were marked by the same pens, and allowed to dry for three months, which included a number of days where the temperatures ranged from the high 80s to about 97 °F (yes, even in the PNW). The intent was to see if any of the markers baked on the surfaces over time, requiring different cleaners to remove them.

The original test used 27 different cleaners, but this Part B test eliminated the 10 least-effective cleaners.

A variety of surfaces were used, including unfinished aluminum, anodized aluminum, paint, fiberglass, gel coat, carbon fiber, plastic and wood. A thanks is extended to the suppliers of these materials: Gill Athletics, Seattle Masters Athletic Club and the PNTF Youth Committee.

The most notable finding was that Krylon Short Cuts Paint Pen markings baked on to all the surfaces very effectively, making then difficult to remove. By comparison, Elmer's Painters Paint Marker and Sharpie markings were far easier to clean off. The Krylon product is easily recommended for anyone needing a durable marking (although it requires some time to cure), but once cured, it requires additional effort to remove.

In general, the cleaners that worked well in Part A also worked well in Part B (except for the Krylon markers). Summary of results:

a. For the aluminum, fiberglass and carbon fiber surfaces, the best cleaners were acetone, Goof-Off Professional, carburetor cleaner, paint stripper, MEK, toluene and xylene (some cleaners smeared into the fiberglass, discoloring it).

b. For painted and gel-coated surfaces, the above list applies, except that paint stripper should NOT be used.

c. The plastic surfaces greatly limit the allowable cleaners because the more aggressive cleaners also begin to dissolve the plastic material. Of commonly-available cleaners, methanol works as well as any other.

d. An old wooden discus, with no apparent surface varnish was also tested (it is assumed that varnish would suffer the same fate as paint, as pertains to the more aggressive cleaners). Interestingly, none of the cleaners could tackle the Sharpie markings, but methanol, carburetor cleaner and Goof-Off Professional did a reasonable job on the paint markers, although care must be taken to not smear the residue into the wood grain.

The Part A results (from February) are summarized at the following link: http://home.comcast.net/~ikstrums/cleaner-solvent-test-01dec09.pdf.
The most recent, Part B, results are summarized at: http://home.comcast.net/~ikstrums/cleaner-solvent-test-part2-30sep10.pdf.

The effectiveness of the cleaners is evaluated as either Excellent, Good, Fair or Poor. For occasional cleaning, even a cleaner with a Fair rating will be adequate for the job because the extra time required should not be a big issue. However, if a large quantity of markings are to be cleaned, then cleaners with Excellent or Good ratings will improve the efficiency of the effort.

THE TRAINING CENTER

This is a regular feature of this newsletter, where we discuss the method of measuring an implement, venue or a track facility. Your comments or areas of interest are welcome. It is through this kind of dialogue that we learn from each other and improve our skills. Send the editor your stories and questions.

CHANGING JAVELIN WEIGHT & BALANCE

During last year's annual meeting the following question was raised: How much does a javelin's weight and balance change if it is covered with a significant amount of markings (i.e., paint)? It would seem the answer is "probably not much," but the editor decided to find out how much.

An 800 g javelin was used for the test. It was initially weighed against mass standards and its weight was determined, accurate to 0.1 g. A repeatable and accurate balance point determination was more problematic. A method was devised to ensure the javelin was level at the time of measurement; the accuracy of this measurement was judged to be about 0.5 mm.

The rear half of the javelin was then marked with a paint stick (from the grip to the rear tip). A paint stick was used on the assumption that it left heavier residue than would a Sharpie. The markings consisted of straight lines that covered approximately 50% of the surface of the javelin. This was judged to be in excess of any build-up of certification markings that would be experienced in real life. The paint was allowed to dry for one day.

The second set of measurements were made identically to the first ones:

	before marking	after marking
weight (g)	804.0	804.3
fwd balance point (mm)	1052.0	1052.5

The above differences will not be noticed by most scales and balance fixtures in the field.

SCALE CALIBRATION

How often does the following happen: A shot or hammer gets disqualified for being underweight. The coach or athlete, who owns the implement, immediately complains, saying that implement has passed inspection the last two or three weeks in a row. "*How* can it possibly be DQ now?" How do you, as the implement inspector, justify the disqualification of that implement? For that matter, how can you justify ***certifying*** an implement that barely makes weight?

This article will look at the issue of weight and weighing scale performance. The following points will be covered:

- some metrology definitions
- a look at the basic types of scale error
- scale resolution (or readability)
- examples of scale error from the field

- some causes of scale error
- how to calibrate, adjust & monitor your scale's performance

What will be discussed here applies to spring scales and electronic scales. Balance beam scales (with poise and counterpoise weights) and balances are not affected by most of the error sources discussed herein.


spring scale


top-loading spring scale


electronic scale


balance beam mechanical scale


mechanical balance

Definitions.
Weight measurement is one aspect of metrology. Unfortunately, the terminology used colloquially and in the metrology world is not universally consistent. Therefore, the following definitions are presented for purposes of this article:

ERROR: This is a calculation of how far the scale's indication is from the true value. A positive error means the scale indicates heavier than the true value; a negative error means the scale indicates lighter than the true value.

TOLERANCE: This is how manufacturers express the performance which a scale is designed to have. Tolerance is frequently mistaken for the accuracy of a scale. As long as a scale is operating within the manufacturer's stated tolerance, it is considered to be operating properly.

ACCURACY: This is a way of expressing how close a scale measures to the true value. Accuracy usually refers to the performance of an individual scale. A scale's accuracy should always be as good or better than its tolerance.

PRECISION: This is a way of expressing how close repeated measurements are to each other. Ideally, a scale will always indicate the same weight for a given object that is weighed repeatedly.

CALIBRATION: This is a comparison of a scale's measurement against a true standard. A calibration only performs a comparison and records the data. An adjustment of the scale is normally only performed if the scale's calibration shows it to be out of tolerance.

ADJUSTMENT: This is the physical or electrical alteration of a scale to bring its measurement in line with the true standard. It may be an adjustment of a small weight for a mechanical scale or balance, or the adjustment of a potentiometer for an electronic scale. An adjustment should be followed by a second calibration to document that the adjustment achieved the required result.

MASS STANDARD: This is a finely-made metal artifact that replicates a particular target mass. There are a variety of classes of mass standards, governed by how close they are to the target mass. In most cases, as long as the *tolerance* of a mass standard is sufficiently better than the tolerance of a scale, the standard can be used to calibrate the scale.

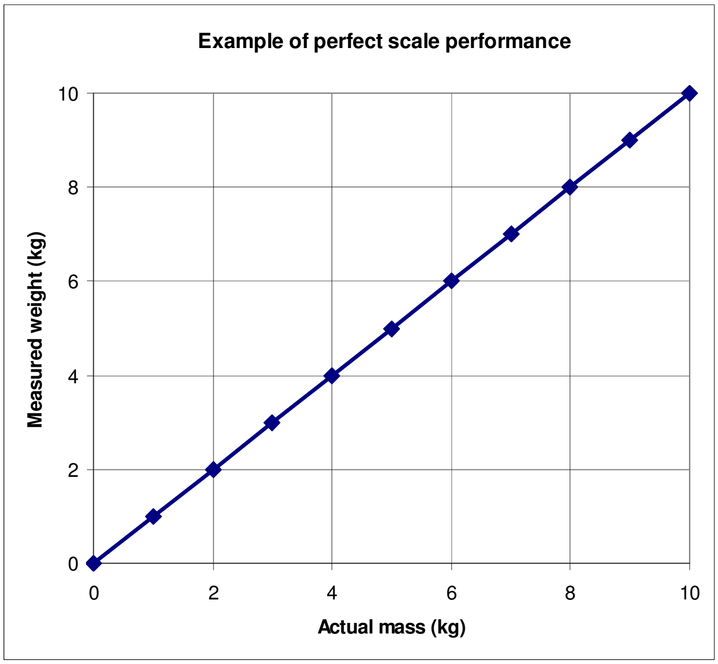
Take, for example, a 1 kg mass standard. On the laboratory side of the spectrum is the OIML Class E-1 standard, which can be no more than ½ milligram (0.0000005 kg) in error from a true 1 kg. On the field-grade side of the spectrum is the ASTM Class 7 standard, which can be no more than 470 milligrams (0.00047 kg) in error from a true 1 kg. Of particular note is the NIST Class F standard, which can be no more than 100 milligrams in error from a true 1 kg – this is used for commercial (legal-for-trade) metrology. Their respective costs are commensurate with the effort it takes to machine and polish them to within their respective tolerances. More about this later.

Basic scale error
During a calibration, one or more mass standards are sequentially placed on a scale, and its readings are recorded. In an ideal world, a scale will read exactly the amount of the mass standards. For example, here are the data from such an ideal calibration:

Calibration #1	
actual mass (kg)	indicated weight (kg)
0	0.000
1.000	1.000
2.000	2.000

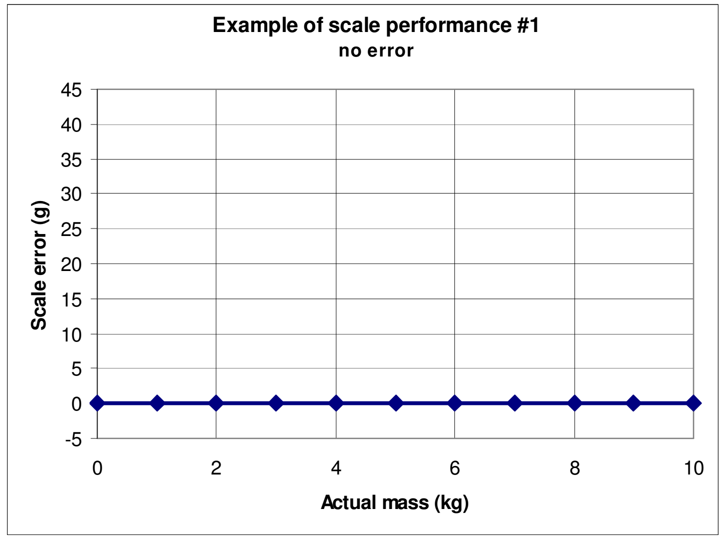
3.000	3.000
4.000	4.000
5.000	5.000
6.000	6.000
7.000	7.000
8.000	8.000
9.000	9.000
10.000	10.000

Plotting the data produces the following graph. The cumulative value of the mass standards is on the horizontal axis; the measured values from the scale are on the vertical axis:

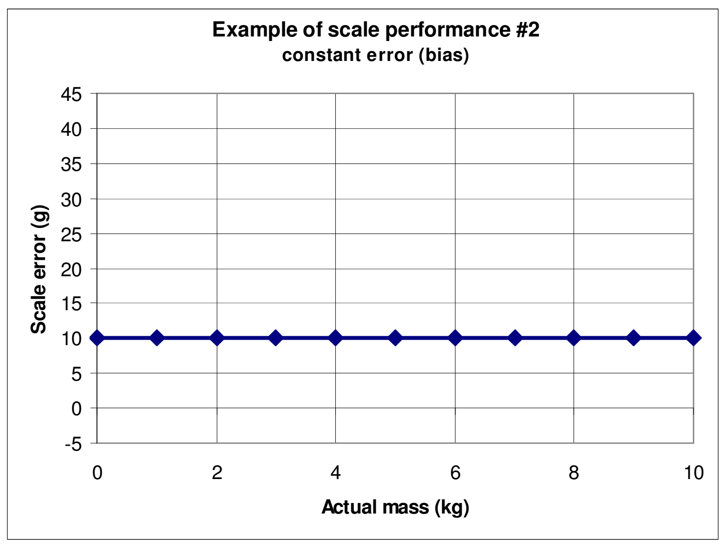


The problem with this plot is that only large errors would be clearly visible. A better approach is to calculate and plot the error of the scale:

Calibration #1		
actual mass (kg)	indicated weight (kg)	error (g)
0	0.000	0
1.000	1.000	0
2.000	2.000	0
3.000	3.000	0
4.000	4.000	0
5.000	5.000	0
6.000	6.000	0
7.000	7.000	0
8.000	8.000	0
9.000	9.000	0
10.000	10.000	0

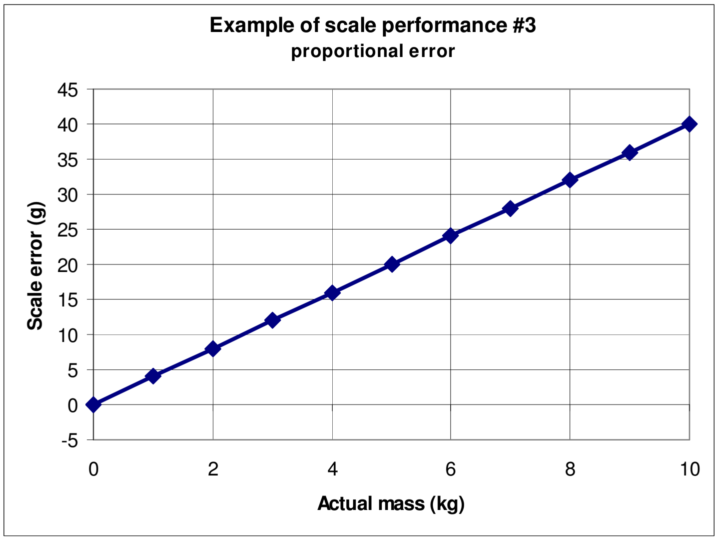


The above plot represents a perfect scale (and nirvana in a metrologist's world). However, this rarely happens in the real world. The next plot shows a second scale that has a constant error of 10 grams at all points along its measuring range:



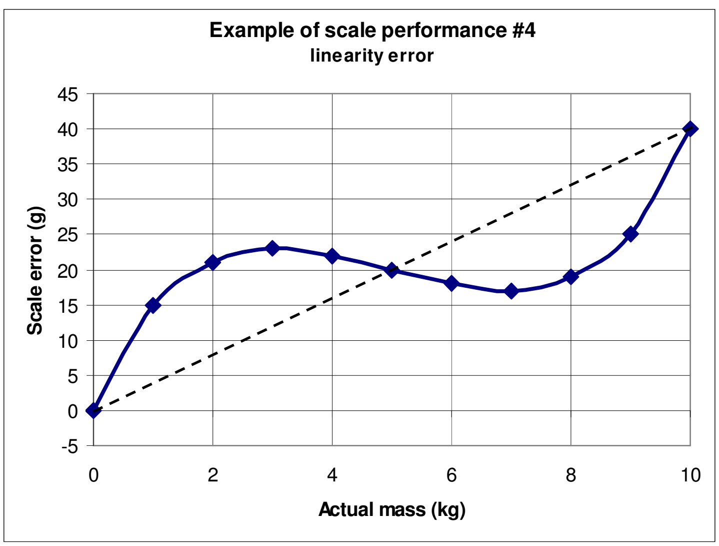
A constant error is also known as *bias*. If this was known to be true, then 10 grams could be subtracted from every measurement to arrive at the correct value. A properly-designed scale should be adjustable to remove any bias.

But once again, a scale with just bias is not a common occurrence. The following plot is more representative of the real world:



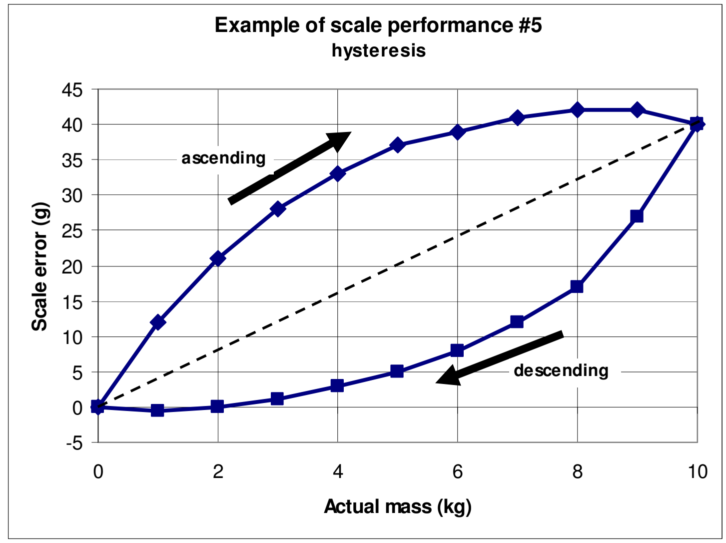
The above plot shows a scale whose error increases steadily with increasing mass. This can be called *proportional* error. In the real world the line won't be perfectly straight, but it will trend predominantly in either the positive or negative direction. Once again, a properly-designed scale should be adjustable to remove any such error.

Of special note are two other conditions. The first concerns linearity error:



The above case is exaggerated, but it shows a scale with *nonlinear* behavior. It also demonstrates why a calibration needs to be done with more than three points – if only the zero, mid-point and max values are calibrated, the plot would show a straight line, which is not really the case in this example. Typically, this type of error can not be removed by adjusting the scale.

The other example shows a classic case of hysteresis (this case is also exaggerated):



In hysteresis, the error plot takes one route to the maximum value, and another route back to zero. Normally this would not be a concern in implement inspection since weighings are done one implement at a time. However, a scale with hysteresis can complicate matters when an implement, such as a throwing weight, is placed on a scale, and parts are removed and replaced for purposes of fine-tuning its final weight. To detect hysteresis, a calibration should be performed by adding the mass standards up to the maximum load, and then removing them in the reverse order. Typically, hysteresis can not be removed by adjustment of the scale.

One final note about scale error. Some scales exhibit a condition called *non-return-to-zero.* After an object is placed on the scale, weighed and removed, the display does not go back to zero; instead, an erroneous residual value is displayed. Frequently the displayed value is the first increment of resolution, like 1, 2 or 5 grams. When this happens, the scale should be manually zeroed before the next weighing. Most electronic scales have both Zero and Tare buttons; ensure you use the Zero button.

Scale resolution (or readability or divisions)

Before continuing, the subject of scale ***resolution*** must be discussed. Resolution is best understood in the context of a digital scale. Therefore, consider a digital scale, which has a display of illuminated numbers that indicate the measured weight. The most right-hand digit of the display is normally built to show increments in amounts of 1, 2 or 5.

In the following example, three scales are shown, which display kilograms with three decimal places (i.e., to the gram level). Scale A can display any value to three decimal places. Scale B can display only even increments of grams. Scale C can display only increments of 5 grams. In short, *resolution* can be thought of as the minimum *increment* the scale can detect and display.

scale	A	B	C
resolution	**1** gram	**2** grams	**5** grams
Progression of the digital display	0.000 kg	0.000 kg	0.000 kg
	0.001 kg	0.002 kg	0.005 kg
	0.002 kg	0.004 kg	0.010 kg
	0.003 kg	0.006 kg	0.015 kg
	0.004 kg	0.008 kg	0.020 kg
	0.005 kg	0.010 kg	0.025 kg

Better resolution (like that of Scale A) implies the scale has more measurement sensitivity. This usually will cost more. Scale C can only display weight to increments of 5 grams, but probably will cost less.

NOTE: Almost all manufacturers of scientific scales provide more resolution than accuracy – it is up to the user to determine the accuracy of that particular scale.

General-purpose and legal-for-commerce scales take a different approach. They specify the range of the scale, its resolution (also called its division), and the total number of divisions. In some cases, one division is the implied accuracy of the scale, although they don't overtly advertise it that way. In other cases, the accuracy may be two or more divisions, but that may not be overtly advertised, either. Once again, it's up to the user to determine what that particular scale can actually do, and if that performance satisfies the original need.

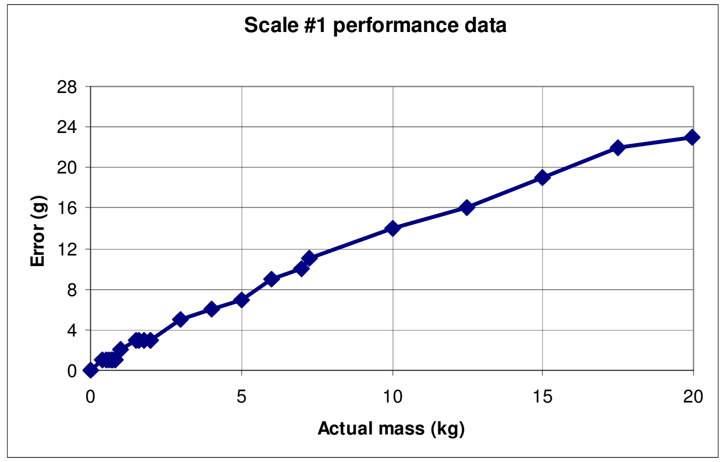
Examples of scale error from the field

At the beginning of this article the following question was essentially asked, "How can an implement pass its weight inspection at one meet, and fail the next week?" This section provides scale error data from the field, which will start answering that question.

The editor has personally calibrated no less than 15 electronic scales during the past year, of which the majority are used only for T&F weigh-ins. The majority of these have never been otherwise calibrated or adjusted since they were shipped from their respective factories. Several representative error plots are presented. Please note the general slopes and trends of the error plots, and also the magnitudes of the errors. In all cases, scale error in grams is plotted on the vertical axis against the true mass values in kilograms.

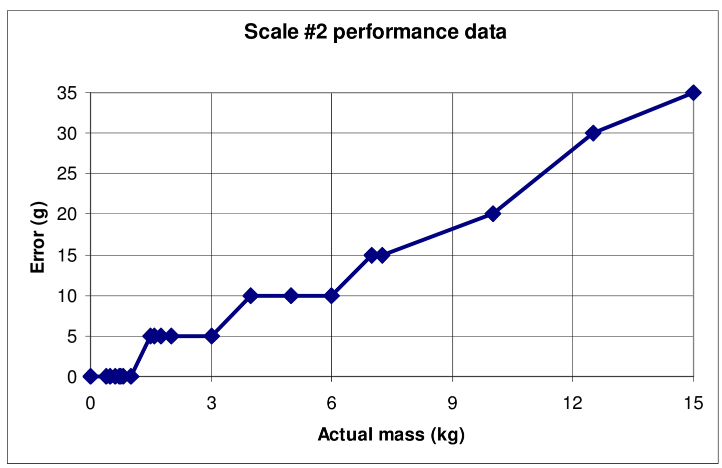
All the calibrations were performed with NIST Class F mass standards, that have been weighed on precision lab equipment, and their actual tolerances have been determined to be approximately ASTM Class 5 or better.

Scales #1-5 are similar in that they all display proportional error in the positive direction. Scales #6-8 all display proportional error in the negative direction. Scales 9 & 10 will be discussed separately.

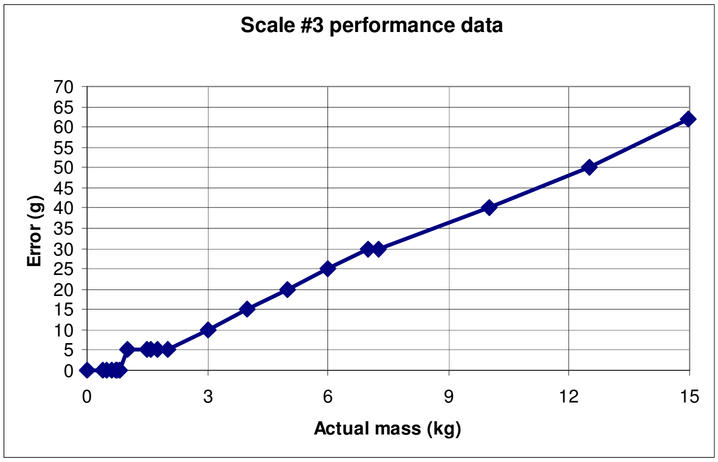


Scale 1 is fairly linear, which is desirable, and its error curve appears smooth because this scale has a resolution of 1 gram. However, the scale produces a fair amount of error. The Taiwan manufacturer does not provide the tolerance specs on their web site.

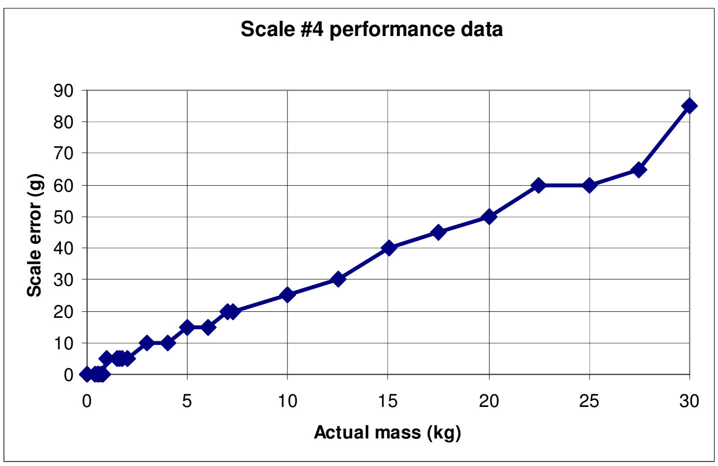
Of particular note is that Scale 1 was newly-purchased at the time of its calibration, and had never been previously used for weigh-ins or other purposes.



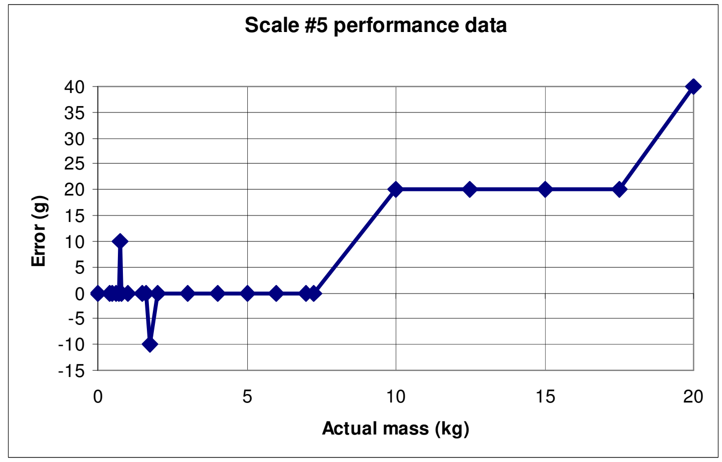
Scale 2 is also quite linear, but its curve appears more jagged because its resolution is 5 grams. In short, Scale 2 can only discern weight in increments of 5 grams, whereas Scale 1's measurements are made to 1 gram, which produces a finer result. The manufacturer implies an accuracy which is equal to one division (5 grams), but that might only be true after this scale was properly adjusted.



Scale 3 also has a resolution of 5 grams, but its curve appears to be smoother than that of Scale 2 because its total error is about twice that of the first two scales. In reality, Scale 3 has the same jagged steps in its error curve as Scale 2, but they are less noticeable because the vertical axis is compressed. The editor attempted to adjust this scale using factory-provided instructions, but the scale did not respond to the adjustment. Hence, this scale continues to produce fairly large errors.

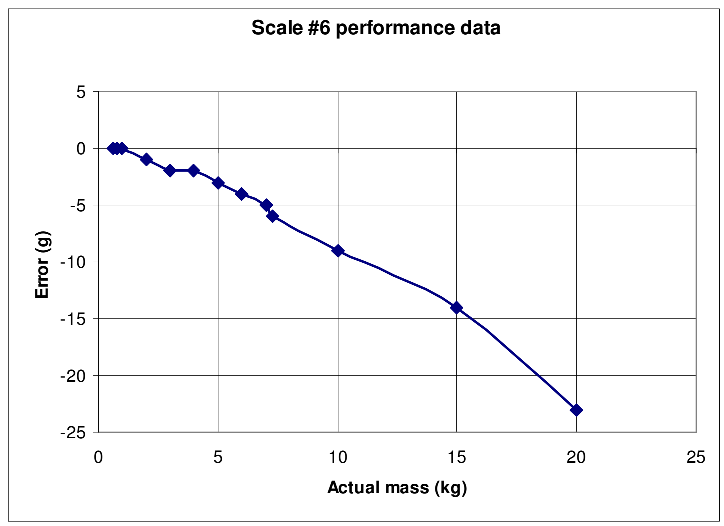


Scale 4 also has a 5 gram resolution, but note the large overall error of the scale, and also the significant non-linearity in its curve at 25 kg. The reason for the non-linearity is not known, since it could be faulty work by the manufacturer, damage incurred by rough use or other reasons.

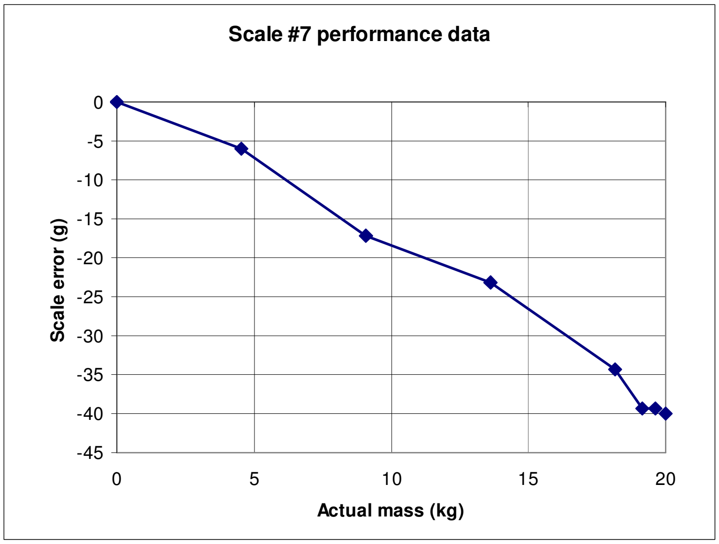


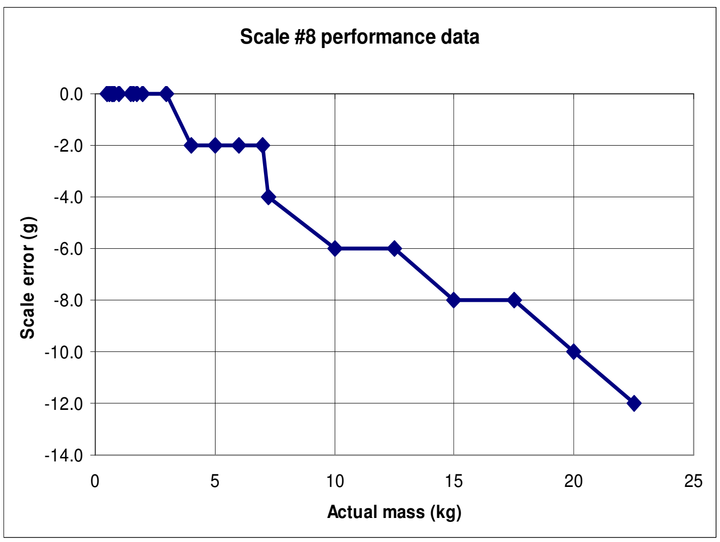
Scale 5 has a resolution of 20 grams, which is quite large when compared to the other scales. Only when the actual error of a weighing specimen exceeds 10 grams does the scale's indication jump to the next 20 gram increment.

Per the US importer of this scale, its factory tolerance is 20 grams. Therefore, at 20 kg, with an error of 40 grams, this scale is out of tolerance. However, this scale is considered to be acceptable thru 17.5 kg (whether a 20 gram error is acceptable in implement inspection is the subject of a different discussion).

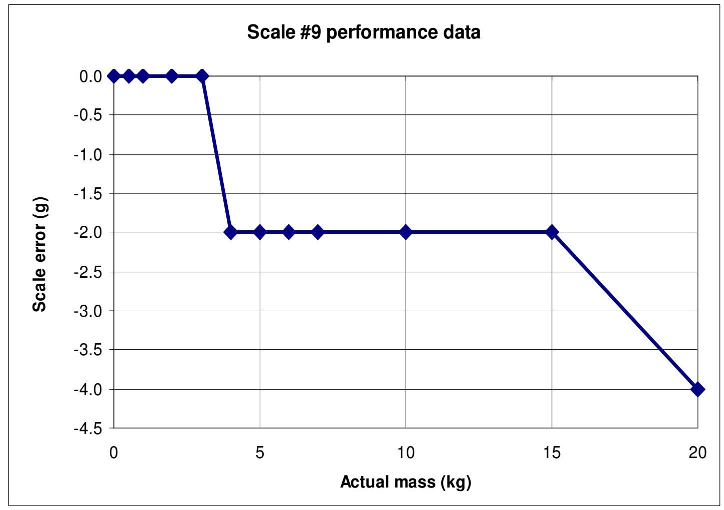


Now on to the scales with negative error trends. Scale 6 & 7 are similar, except Scale 6 has a resolution of 1 gram, and Scale 7 is 5 grams. Also, Scale 7 has a notably larger error. Neither scale has a factory tolerance that could be found in a literature search.

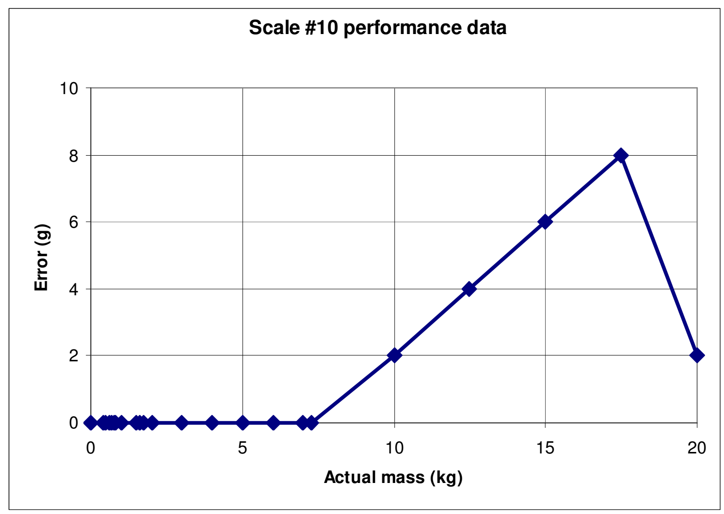




Scale 8 has a relatively small amount of total error (compared to the previous scales), which is why its 2 gram resolution shows up as a jagged error plot. However, the factory specs indicate this scale's tolerance is ±2 grams. Therefore, this scale is out of tolerance and requires adjustment.



Scale 9 also has a 2 gram resolution, but it has no error between zero and 3 kg, and -2 grams error from 4 to 15 kg. This scale's tolerance is known to be ±4 grams; therefore, this scale's actual performance is within the factory tolerance.



Scale 10 demonstrates an extreme case of non-linearity. It has a perfect, flat response to 7 kg, followed by a steep proportional response to 17.5 kg, and then it falls off sharply. The final data point at 20 kg varied with every weighing, making this scale unusable at 20 kg (poor repeatability, poor precision at 20 kg). Per the distributor, this scale's tolerance is about 7 grams, making it within specification up thru 15 kg.

A summary of these data plots could say the following:

- Scales 1-5 indicate too high. They can take an underweight implement and make it look legal.

- Scales 6-9 indicate too low. They can take a legal implement and make it look underweight.

Combining these two conclusions, it should be easy to see why certain implements can pass a weigh-in one week, and fail it the next week. This is particularly true if the two opposing scales were #3 and #7 because they both have relatively large errors in opposite directions.

Here's one other issue that is important to repeat and understand: Most of these scales have not been calibrated and adjusted by their owners since they were purchased (Scale #1 was brand-new and unused when it was calibrated by the editor). The error plots for most of these scales ***could be reduced*** noticeably if they received a proper calibration and adjustment.

Causes of scale error

In general, electronic scales are subject to more different types of error. Among them are the following:

a. temperature and humidity (or changes in temperature and humidity)
b. mechanical shock to the scale
c. operating the scale in a large magnetic field
d. operating a scale that is not level
e. overloading the scale
f. not understanding the scale's tolerance
g. the particular location on the earth where the scale is located

The above list is not all-inclusive, but gives an idea of what factors can affect a scale's performance. Here are some comments about the above points:

a. **Temperature and humidity.** A well-designed electronic scale will have a temperature-compensating circuit built into it that works well. Less expensive scales may have such a circuit, but it may partially correct for temperature. Most scales do not compensate for humidity, but humidity affects a scale less than does temperature.

b. **Mechanical shock** can permanently distort the structure of the scale. The result could be an overall bias in its reading, or a non-linearity in its output (like Scale #4 in the examples).

c. **Magnetic field.** Operating a scale next to a power panel or a wall which contains power feeder wiring will affect the scale's performance. Such areas need to be avoided.

d. **Level scale.** All scales need to be leveled before using them. Some scales have a built-in bubble level; others will require you to buy a small torpedo level or pocket level.

Included with this topic is where a scale is placed. When placing a scale on a portable table, it should either be directly over the legs on one side, or in the middle. Most portable tables will sag under some weight, and the scale will tilt if it's not in the center or even with the legs.

e. **Overload.** Every scale should have a maximum capacity written on it somewhere. Many scales can go up to 50% over the maximum load without affecting the calibration, although the reading will not be accurate. Some can go 100% over the maximum load before permanent damage occurs (check your scale's specifications first, though). However, at one overload point, every scale will be damaged. This can happen from simply placing something too heavy on the scale, or by carelessly dropping an object on the scale (shock).

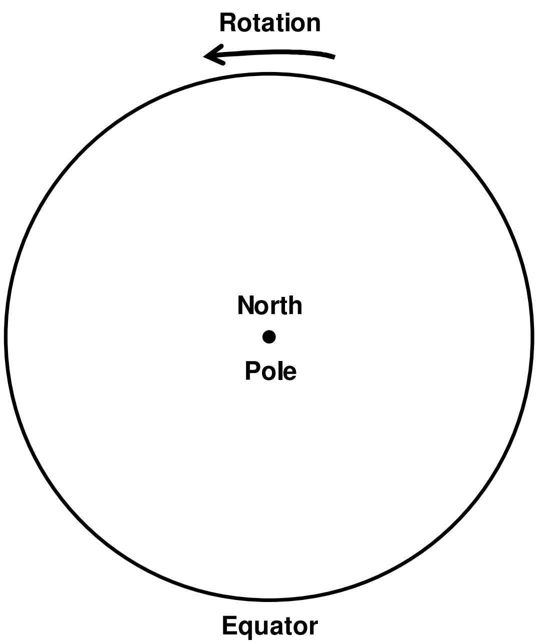
f. **Tolerance.** Assume for a moment that a scale's factory tolerance is ±10 grams. What does this really mean? As long as the scale indicates a measurement that is no worse than 10 grams from the true value, it said to be operating properly. This means the following:
- If the scale is operating perfectly (with no error), then all measurements will produce the true weight of an object.
- If the scale is indicating 10 grams high (the top end of its allowed tolerance), it will make all weighed objects appear to be 10 grams heavier than they really are. For example, an underweight 4.990 kg shot would appear to be a legal 5.000 kg shot on this scale.
- If the scale is indicating 10 grams low (the low end of its allowed tolerance), it will make all weighed objects appear to be 10 grams lighter than they really are. For example, a legal 5.005 kg shot would appear to be illegal at 4.995 kg on this scale.

Only a calibration will tell you for sure exactly where your scale is operating with respect to the Truth.

g. **Location on the Earth.** There are several things about the earth that can affect a scale's performance: latitude, altitude, air density and the nature of ground in the local area. Latitude is frequently the most significant source of error and is discussed next.

Most people assume the earth's gravity is the same, regardless where in the world they may be. In reality, this is not true, and it will affect how a scale will function.

The earth rotates once every 24 hours, and that causes complications. Picture the earth as viewed from outer space, directly above the North Pole.

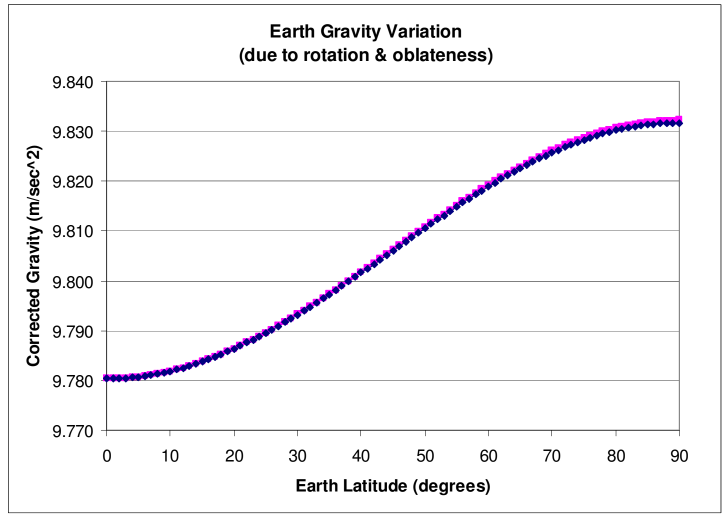


A person at the pole will rotate around once in 24 hours, which is insignificant to this discussion. However, someone at the equator is moving with the earth at slightly over 1,000 mph. This is normally not noticed because the atmosphere moves with the earth, but it does create an effect that a scale will notice.

Being at the equator is similar to holding on to the outer edge of a merry-go-round: a person hanging on in this fashion is constantly changing their direction of motion. The sensation is like the merry-go-round is trying to fling the person off (this effect is sometimes erroneously called centrifugal force).

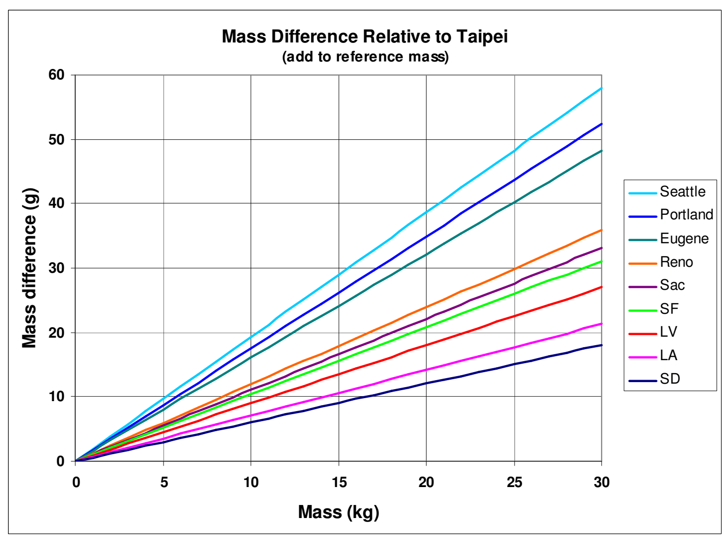
Although this flinging effect is less noticeable at the equator than on a merry-go-round, it is still measurable. For example, a person on the equator, who weighs 189 lb on a properly-adjusted scale, will weight one pound more at the North Pole on the same scale. While this difference is not very large, it can affect all scales, depending on *where* they were last calibrated and adjusted, and *where* they are now being used.

In high school chemistry or physics we were taught that the acceleration of gravity is 9.81 meters / second^2. In reality, that is an average value, which does not account for the rotating earth. The following graph shows the variation of gravity at different latitudes due to the rotating earth, and that the earth is slightly oblate (it has a larger diameter at the equator than across the poles):



Using the above information, predictions can be made how much the *apparent* weight of an object will change as it moves North or South on the surface of the earth. Since many of the imported electronic scales come from Taiwan, the latitude of Taipei (capital of Taiwan) will be used as the reference: 25° North.

The following graph assumes that an electronic scale is properly calibrated and adjusted in Taipei. Then, without any further adjustments, it is used to weigh mass standards in nine locations: Seattle, Portland, Eugene, Reno, Sacramento, San Francisco, Las Vegas, Los Angeles and San Diego (colored lines, top to bottom):



As long as the scale is not readjusted after the initial adjustment, it will *appear* that the mass standards gain in weight as the weighing location moves north. In reality, the mass standards stay the same, but the slower rotation (tangential speed) of the earth at higher latitudes creates the *effect* of greater apparent weight. Even moving the scale between cities like Seattle/Portland or LA/San Diego produces a measurable effect in the scale's performance.

The above graph is shown to demonstrate that gravity (and, therefore, the apparent weight of an object) changes measurably as latitude is changed. However, a change in altitude will have a similar, although usually smaller, effect. And even the composition of the earth under one's feet can change the local value of gravity.

Given that gravity can be different almost everywhere we might travel, this raises a troubling problem: Does an object's actual weight change as it travels the earth? The true answer is Yes (the variation is less than 0.5%, but many of our scales can detect that).

This problem was considered over a hundred years ago because it had significant implications in the area of commerce, where products are sold on the basis of weight. In 1901 the international General Conference on Weights and Measures was convened to consider such problems. The conference adopted a standardized value of gravity as 9.80665 m/s^2, which approximated gravity in the middle of the developed world, as it existed at that time. This standardized definition of gravity, along with the previous adoption of the International Prototype Kilogram as the world's mass standard, allows us to adjust and calibrate scales to read identically everywhere in the world.

And this is why:
- **a newly-purchased scale needs to be adjusted and calibrated in the local area of its intended use**, and
- **if a scale is moved to a new location, it either needs to be adjusted/calibrated for the new location, or corrections need to be applied to its readings** (see exceptions below).

Two types of scales are exempt from the second point above:

1. balances, balance beam and counter-poise scales (like the old Trackmasters)
2. self-calibrating electronic scales (because they electronically adjust themselves whenever they are turned on)

The variation in apparent gravity only partially explains some of the scale error shown in the previous section. It could be argued that Scale #2 comes closest to the error between Taipei and Seattle that is shown in the last graph. But the other scales either diverge from that calculation, or have the opposite slope. Therefore, it can be argued that some of these scales may not have been adjusted in their factories at all. This further underscores the need to calibrate and adjust scales after buying them, and then on a regular basis afterwards.

Calibrating, adjusting and monitoring your scale's performance

A calibration at an accredited laboratory will take one of two forms.

1. **Case #1**: The scale will be calibrated by the lab and will be found to be in tolerance, based on the factory specifications. No more action will be taken by the lab because the scale is operating the way it was designed.

2. **Case #2**: The scale will be calibrated by the lab and will be found to be *out* of tolerance, based on the factory specifications. The scale will be adjusted to bring it into tolerance. Then a second calibration will be performed to demonstrate that it is performing per the factory specs.

At this point the lab *should* print a certificate that attests to the scale's calibrated performance. The certificate will take one of two forms:

a. **Certificate without data**: This certificate will simply identify your scale by make, model and serial number. It will also provide the date, identification of the lab and a statement that the scale is within tolerance.

b. **Certificate with data**: All of the above will be on the certificate, but all the calibration data will also be provided.

The certificate with data will cost a bit more, but will enable you to track the long-term performance of your scale. This option is highly recommended.

You should request the calibration with "before" and "after" data (sometimes called "as received" and "as left" data). If the scale was in tolerance, there will be only the "before" data since only one calibration (and no adjustment) was needed to be performed. If the scale was out of tolerance, the certificate will list both sets of data since the out-of-tolerance condition and the final proof of adjustment must be provided.

How often should a scale be calibrated? The general answer is, "it depends on the usage and the criticality of the measurements." The following are the editor's recommendations:

1. Once per year at the start of the track season.
and
2. prior to any major meet
and
3. at any time (a) damage to the scale is suspected, (b) a heavier implement (shot, hammer, weight) is accidentally dropped on the scale, or (c) previous calibration data indicate the scale drifts and requires more frequent adjustments.

Once the above is accomplished, then a second step can be taken. A mass standard can be purchased, or a mass artifact can be made. The purpose of these is to check the performance of the scale at one point prior to each use. Regardless which is picked, it should be somewhere near the maximum capacity of the scale, but no less than half the max capacity.

A mass standard is an absolute mass value, within the tolerance of its specification. NIST Class F is recommended for this application (ASTM Class 6 is approximately equal to NIST Class F). It will provide the same pedigree of calibration which the cal lab uses, except that only one point is checked, unless more standards are purchased. NIST Class F standards can be purchased from:
Rice Lake Weighing Systems
(**http://www.ricelake.com/categories.aspx?CatID=3202**),
Henry Troemner LLC
(**http://www.troemner.com/weights_classF_stainlesssteel.php**) and McMaster_Carr
(**http://www.mcmaster.com/#weights/=8vi360**).

A mass artifact, in this context, will be a smooth, clean piece of metal that henceforth will only be used to check the scale. It will be stored in a padded box and not used for any other purpose. Weigh it on the scale immediately after the scale returns from the calibration lab, and record that value. This will be the check value in the future.

Whenever the scale is used after that, check it first with the standard or artifact – if the measured value is different than the original value, then the scale either has drifted, has been damaged, is affected by an environmental variable, or it has been moved in latitude or altitude. Assuming the scale's basic performance is linear, a simple ratio can be calculated to correct the measurements.

Summary: This article has discussed a variety of factors that contribute to errors in weight measurement, particularly as pertains to electronic and spring scales. As measurement errors will manifest in different ways on different scales, it should be no surprise that some implements, which are on the borderline for legal weight, will pass on one scale and fail on another.

Real-world data was included herein to show a small sampling of the magnitudes of errors that are present in T&F scales.

The single most important step that can be taken to eliminate these errors is to periodically have your scale calibrated, and adjusted, if necessary. Keeping the calibration data from your scale over the long term will also enable you to see trends in the scale's performance.

Looking ahead: Of the ten scales whose calibration data were shown, the full-range errors varied between 4 grams and 85 grams. This prompts the following questions:
- How much scale error is too much?
- How much scale error is tolerable for our purposes?

For a 20 kg scale, an accuracy of no worse than ±2 grams is ideal (and expensive). An accuracy of ±7 grams is acceptable. The rationale for these values will be examined in the next newsletter. Since the actual accuracy of a scale won't be known when it's purchased, the factory tolerance will have to suffice when comparing different scales.

Additionally, picking out a scale (tolerance and resolution vs. cost) and making measurement corrections will be discussed.

UPDATED DOCUMENTS FOR 2010

The **W&M Handbook** was updated earlier this year. It is available at
http://www.usatf.org/groups/officials/resources/weights-and-measures/

The **Ultraweight Throwing Rules Supplement Manual** is available at:
http://www.pntf.org/masters/documents/Ultraweight_Rules_Monograph_12-14-08.pdf

Past **EFSS newsletters** are located at:
http://www.usatf.org/groups/officials/newsletters/#efs

Ultraweight throwing square drawings:
http://home.comcast.net/~ikstrums/uw-throwing-square-dwg.pdf