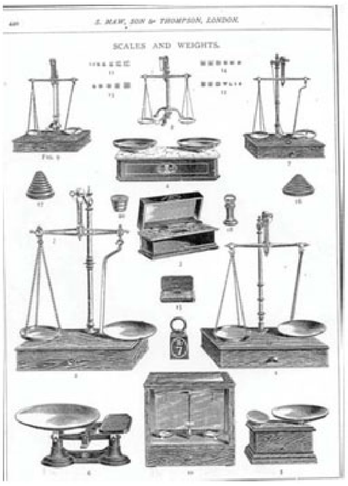
Weighing Scale Terminology



Weighing Scale - A device used to determine weight. Weighing scales are divided into two main categories: Spring Scales and Balance Beam Scales. Balance beam type scales are the oldest type and measure weight using a fulcrum or pivot and a lever with the unknown weight placed on one end of the lever, and a counterweight applied to the other end. When the lever is balanced, the unknown weight and the counterweight are equal. Spring scales were introduced in the 1760's as a more compact alternative to the popular steelyard balance. Spring scales work based on the principal of the spring which deforms in proportion to the weight placed on the load receiving end. Strain gauge scales became popular in the 1960's and used a special type of spring called a load cell. Strain gauge scales are the most commonly used in todays market but electronic force restoration balances are used in laboratory and high precision applications.

Accuracy - The degree to which a measurement relates to its actual (true) value. Accuracy is a hot topic of debate in the weighing industry as the usage of the term varies between weighing professionals. Accuracy is usually stated as a percentage and it is important to determine if the percentage is that of full scale (%FS) or that of actual reading (%AR). All measuring devices have some degree of inaccuracy since infinite precision can never be achieved. Some of the primary factors contributing to scale accuracy are readability, repeatability, linearity, and uncertainty of measurement. The accuracy of a weighing device can only be determined by direct testing of the device at its intended location of use. Usually when the term accuracy is applied to scales, the intended meaning is inaccuracy. So, if a scale manufacturer claims an accuracy of 1%F.S., they mean the scale should have an error of less than 1% of full scale if the scale has been properly adjusted.

High Accuracy, Low Precision

Repeatability (also Precision) **–** This is a scale's ability to show consistent results under the same conditions. To determine a scale's repeatability, a test weight should be weighed ten or more times in a consistent manner. The resulting values are recorded and used to calculate the standard deviation. This standard deviation value is used to express repeatability.

High Precision, Low Accuracy

Reproducibility – This is the scale's ability to show consistent results under changed conditions.

Adjustment (also Calibration Adjustment) - The set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured. Scales are subject to constant wear and tear which over time can degrade accuracy. Adjustment corrects a scales accuracy so that it is within the tolerance applied to the device. Many times people refer to calibration when they actually mean adjustment. Calibration only refers to the process of measuring a known standard to determine the error of a scale's measurements.

Calibration (also Cal)- The set of operations that establish, under specified conditions, the relationship between the values of quantities indicated by a measuring instrument and the corresponding values realized by reference standards. Basically, calibration is the process of weighing a known weight on a scale and noting the discrepency (if any) on the display. Calibration should not be confused with adjustment of a measuring system. (see Adjustment)

Maximum Capacity (also Max Capacity, Max, Rated Capacity) - This is the maximum weight that can be measured using a particular scale. When selecting a scale, the heaviest item you plan to weigh should be within the scale's maximum capacity limits. It is a good idea to select a scale with slightly more capacity than you will need to avoid overloading. However, the higher the capacity is on a scale, the lower the readability typically will be. Therefore, you should avoid selecting a scale with too much capacity.

Readability (also Resolution, Scale Division, Scale Interval, Increment, Digit, d) – On electronic and digital scales, this is the smallest change in mass that corresponds to a change in displayed value. In other words, this is the amount that the scale will increment by as weight is added or removed. On analog (mechanical) scales, this is the smallest subdivision of the scale dial or beam for analog indication. Example:

152.358g is weighed on a scale with 0.001g readability
The display will read "152.358g".

152.358g is weighed on a scale with 0.01g readability
The display will read "152.36g"

Readability should not be confused with accuracy which is a separate concept. When properly calibrated and adjusted, most scales will be accurate to within plus or minus two scale divisions (+/-2d), though this can vary depending on individual specifications.

Verification Scale Interval (also Verification Scale Division, e) - This is the smallest scale interval that can be used to determine price based on weight in commercial transactions for a particular scale. The value of the verification scale interval (e) is determined by the scale manufacturer when submitting a device for type approval through a program such as NTEP (or CE for EU countries). Many times, a scale will have a verification scale interval that is different than the normal or actual scale interval. For instance, the scale could be capable of displaying in increments of 0.01g, but its verification scale interval is specified as 0.1g. In this situation, you could only charge a customer based on 0.1g increments although the scale has the ability to display 0.01g increments. This is why some manufacturers place brackets around the last digit to indicate that it should be omitted when calculating a price based on weight.

Uncertainty of Measurement – This is a parameter that is used to state the quality of a measurement. Because no measuring instrument is 100% accurate, scientists and researchers use measurement uncertainty to express the distribution of errors associated with a measurement. There are various methods employed to calculate and express measurement uncertainty.

Accuracy Class- Weighing Devices are classified into groups according to the number of scale divisions (n) and the value of the scale division (d or e). The accuracy classes are meant to determine the intended area of use for a particular scale.

Class	Value of the Verification Scale Interval (e) in SI Units	Number of scale divisions (n)		Intended Application
		Minimum	Maximum	
I	$\geq$1 mg	50,000		Precision Laboratory Weighing
II	1 to 50 mg, inclusive	100	100,000	Laboratory weighing, precious metals and gem weighing, grain test scales, medical cannabis
	$\geq$100 mg	5,000	100,000	
III	0.1 to 2 g, inclusive	100	10,000	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
	$\geq$5 g	500	10,000	
IIIL	$\geq$2 kg	2,000	10,000	Vehicle scales, vehicle on-board weighing systems with a capacity greater than 30,000 lb, axle-load scales
IIII	$\geq$5 g	100	1,200	Wheel-load weighers and portable axle-load weighers used for highway weight enforcement

NTEP Approval – NTEP is a program administered by NCWM for evaluating weighing devices for their conformity to NIST Handbook 44. Scales that pass NTEP certification are deemed "legal for trade" and can be used in commercial transactions based on weight. When a device is submitted to NTEP, extensive testing is performed to insure it meets the tolerance requirements that apply to its accuracy class. A Certificate of Conformance is issued to a scale manufacturer upon successful completion of testing. You can search the complete database of issued Certificates of Conformance by following this link: http://www.ncwm.net/certificates

Approval Seal - A label, tag, stamped or etched impression, or the like, indicating official approval of a device. This is placed on a legal for trade scale after it has been inspected and shown to perform within the acceptable tolerances for it's accuracy class. A local "sealer" from the Department of Weights and Measures will periodically conduct inspections of scales used in commercial transactions similar to how they inspect and seal gas pumps being used in commercial transactions at your local gas station. This is why it is important for businesses that use scales in commercial transactions to purchase one that is NTEP approved and have it professionally calibrated periodically. If a local sealer believes that your business may be using a scale to provide goods or services, they may conduct a random inspection. If a non-NTEP approved scale is being used, they may impose heavy fines and require that the owner purchase an NTEP approved scale before they can conduct business. If an NTEP approved scale is found to be out of calibration, the device may be labeled "out of service" by the sealer until it has its calibration properly adjusted and the owner may be fined, especially if the scale is found to be weighing in their favor.

Calibration Certificate - A Calibration Certificate is a document provided and signed by a calibration technician that documents the completion of a successful calibration. The certificate will typically list the standard that was used to calibrate the device and provides traceability to the internationally defined standard. Calibration certificates for weighing devices can only be issued by testing the device at the site in which it will be used. This is due to the change of local gravitational acceleration which can vary as much as 0.5% at various locations around the world. Calibration certificate is no longer valid if the device is shipped to another location.

Load-Receiving Element - That element of a scale that is designed to receive the load to be weighed; for example, platform, deck, rail, hopper, platter, plate, scoop. The dimensions of the load-receiving element or platform should be considered when selecting a scale. You can often use a scale with a platform slightly smaller than the object(s) being weighed as long as the load is stable and does not lean against anything except the load-receiving element, and is under the scales max capacity. You can also use an expansion tray or container to effectively increase the size of the weighing platform or load-receiving element on smaller, compact scale.

Electromagnetic Force Restoration (also EMFR, Force Motor) **–** Traditional equal arm balances work on the principal of the fulcrum and lever. An unknown mass is placed on a pan at one end of a lever, while a set of known masses or test weights are placed on a pan at the other end to create a balance. Electromagnetic force restoration balances also use a lever system but a magnetic field is used to generate the force on the opposite end of the lever and balance out the unknown mass. The current used to drive the magnetic coil is proportional to the mass of the object placed on the platform. Most analytical and laboratory balances are of the EMFR type. EMFR balances are characterized by high accuracy, high repeatability, and high complexity compared to other weighing sensors.

Load Cell - A load cell is a type of transducer that converts force into an electrical signal. Strain gauge based load cells are the most common type. They consist of (in most cases) four strain gauges that are attached to a beam or other structure. As weight is added to the load receiving end, the beam or structure deforms. When load cells first emerged, they were mainly used for industrial applications where courser resolutions were suitable. Today though, modern advancements in weighing technology have made load cells capable of much higher resolutions. Load cells are characterized by high durability, high reliability, and low cost.

Internal Statement Number (also Inner Code, ISN) **–** In load cell based scales, this is the raw count from the scale's ADC(analog-to-digital converter). This value increases and decreases in proportion to the weight added or removed from the platform. The ISN is usually displayed during calibration adjustment.

Weight - The force that results from the action of gravity on matter.

Mass - The measure of the amount of matter in a body.

Mass vs. Weight - In everyday situations, when people refer to mass and weight, they mean the same thing. In scientific situations, weight and mass represent different quantities. The weight of an object is the magnitude, W, of the force of gravity on that object and is proportional to its mass.

$$W = m \times g$$

Where	W	=	weight
	m	=	mass
	g	=	local gravitational acceleration (9.8 m/s^2 avg. for Earth)

Kilogram, "kg" - the base unit of mass in the International System of Units (SI Units). It is equal to the mass of the International Prototype Kilogram (IPK).

International Prototype Kilogram, "IPK" - The kilogram was originally the mass of a cubic decimeter of water. In 1889, the 1st CGPM sanctioned the international prototype of the kilogram, made of platinum-iridium, and declared: This prototype shall henceforth be considered to be the unit of mass .The International Prototype Kilogram is stored and maintained at the International Bureau of Weights and Measures (French Abbreviation: BIPM) along with its six official copies. The kilogram is the only SI unit still defined by a physical artifact. Efforts are being made though to produce a future, more stable kilogram standard that can be reproduced in a laboratory using written specifications. One such project uses a sphere of a specific number of silicon atoms to define the kilogram. Experiments from this project have produced some of the most near-perfect man-made spheres to date. Other projects use an electronic approach, such as the NIST's watt balance which measures the electric power necessary to oppose the weight of a kilogram test under earth's gravity.

Gross Weight - The total weight of the object being weighed including its vehicle, packaging, or container. Gross weight is typically required for calculating the shipping or transportation charge.

Net Weight - The weight of an object being weighed, discounting the weight of its vehicle, packaging, or container. Net weight is useful for calculating the charge, tax, or payment required for items.

Tare Weight - The weight of an empty vehicle, package, or container. Tare weight is sometimes written on the outside of railcars or shipping and packing containers for quick determination of the net weight during weighing operations.

Average Piece Weight (also APW) **–** On counting scales, this is determined by dividing the weight by the number of samples on the platform. Counting scales work on the assumption that the parts being counted are all of uniform weight.

Tare Mechanism - A mechanism (including a tare bar) designed for determining or balancing out the weight of packing material, containers, vehicles, or other materials that are not intended to be included in net weight determinations. Most electronic scales have a tare button or feature which is used to reset the display value to zero when a container is placed on its load-receiving element. If the vehicle or container is then filled, the displayed weight will be that of the contents alone (see Net Weight). If the vehicle or container and its contents are removed from the scale, a negative weight value is typically displayed equal in absolute value to the Tare Weight.

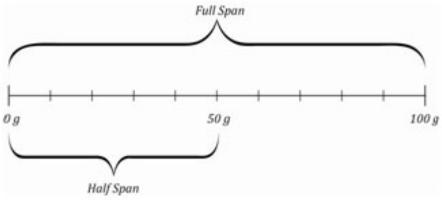
Zero-Setting Mechanism - Means provided to attain a zero balance indication with no load on the load-receiving element. Three types used in scales are:

Automatic Zero-Tracking Mechanism (also Auto Zero) - Automatic means provided to maintain the zero balance indication within certain limits, without intervention of an operator. Environmental conditions as well as internal noise on the circuit can cause the scale's display to drift. The auto zero feature helps to eliminate these unwanted changes in display output and insures that the scale is properly zeroed before each weighing. However, the auto zero feature can be a problem when trying to weigh very small amounts that within the auto-zero range. For instance, if a scale has an auto-zero range of 0.2g and you place less than 0.2g on the scale, the display will not change.

Manual Zero-Setting Mechanism - Nonautomatic means provided to attain a zero balance indication by the direct operation of a control.

Semiautomatic Zero-Setting Mechanism - Automatic means provided to attain a zero balance indication requiring a single initiation by an operator.

Span - The distance between adjoining sections of a scale.



Types of Weighing Scales

Analytical Balance - One which measures mass to a very high degree of precision and accuracy. Most analytical balances have a scale division of 0.1mg or better (0.0001g).

Animal Scale - A scale designed for weighing single heads of livestock.

Checkweighing Scale - One used to verify predetermined weight within prescribed limits. These scales are typically used in weighing operations where the operator must fill and weigh a product to ensure uniform weight. Some checkweighers will activate remote switches or sound a buzzer when the target weight has been met.

Counting Scale - One used to weigh multiple objects of uniform weight and display a total piece count.

Computing Scale - One that indicates the money values of amounts of commodity weighed, at predetermined unit prices, throughout all or part of the weighing range of the scale.

Crane Scale - One with a nominal capacity of 5000 pounds or more designed to weigh loads while they are suspended freely from an overhead, track-mounted crane.

Jewelers' Scale - One adapted to weighing gems and precious metals

Microbalance - A special balance which has a readability of 1 microgram (1µg) or better. A microgram is one millionth of a gram (0.000001g). These devices require special care to minimize weighing errors associated with weighing quantities.

Multi-Interval Scale (also Multi-Range, Dual Range) - A scale having one weighing range which is divided into partial weighing ranges (segments), each with different scale intervals, with each partial weighing range (segment) determined automatically according to the load applied, both on increasing and decreasing loads.

Postal Scale - A scale (usually a computing scale) designed for use to determine shipping weight or delivery charges for letters or parcels delivered by the U.S. Postal Service or private shipping companies. A weight classifier may be used as a postal scale.

Point-of-Sale Scale - scale used to complete a direct sales transaction.

Prescription Scale - A scale or balance adapted to weighing the ingredients of medicinal and other formulas prescribed by physicians and others used or intended to be used in the ordinary trade of pharmacists.

Vehicle Scale - A scale adapted to weighing highway, farm, or other large industrial vehicles (except railroad freight cars), loaded or unloaded.

Weight Classifier - A scale that rounds weight values up to the next scale division. Normal scales have a "breakpoint" midway between scale intervals. A weight that falls between the scale intervals may round up or down to the nearest scale interval. Since weight classifiers are meant to be used in postal and shipping applications, the breakpoint for displayed weight is at the scale interval rather than between. Any partial unit of resolution above a given weight is rounded up to the next scale interval. Example:

Normal rounding instrument with e=d=0.1 will indicate:
1.0 if the load is 0.96 to 1.04, and
1.1 if the load is 1.06 to 1.14.

Postal or shipping weight classifier instruments with e=d=0.1 will indicate:
1.0 if the load is 0.91 to 1.00, and
1.1 if the load is 1.01 to 1.10.

Wheel-Load Weigher - Compact, self-contained, portable weighing elements specially adapted to determining the wheel loads or axle loads of vehicles on highways for the enforcement of highway weight laws only.

Sources of Error in Weighing Instruments

Environmental Factors - A scale's accuracy and precision are highly dependent on the environment in which it is installed. Several environmental factors can affect the scales measurement including:

> **Air Currents / drafts -** These account for most large random errors. Be sure to use your weighing device in an area free of any drafts or air currents that may affect the weight readout. On high precision analytical balances (0.1mg or better), glass draft shields are required. Care should also be taken when weighing objects that are hot or cold inside a draft chamber. The effect of convection currents can make cold objects appear heavier, and hot objects appear lighter.
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> **Air Buoyancy -** The upward force, caused by atmospheric pressure. The net upward buoyancy force is equal to the magnitude of the weight of air displaced by an object. Air buoyancy is mostly a concern when weighing objects of relatively low density.
>
> **Temperature -** Spring scales and load cell scales deflect at a lower rate and consequently perform poorly under cold conditions. Most springs and load cells are temperature compensated to counteract this source of error to a degree. The scale should always be used within the manufacturer's recommended operating temperature. For most scales this is between 32°F and 104°F. When moving a scale from one climate to another, you should allow the internal components to acclimate their new environment before performing calibration.

Zero Error - Occurs when the weighing curve shifts by a constant amount. For the most part, you can avoid this error by using the re-zero function before performing a weighing.

Sensitivity Error - Quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured. Sensitivity of a measuring system can depend on the value of a quantity being measured increasing linearly with heavier loads. Sensitivity errors can occur from temperature drift, aging, adjusting with an incorrect calibration weight, or incorrect compensation of an off-center load error.

Linearity - This is the ability of a scale's characteristic curve to approximate a straight line. Linearity can be tested by weighing several test weights of increasing value up to maximum capacity and plotting them as points in a graph. The linearity would be the maximum amount that the points deviate from a straight line going from zero to max capacity.

Random Error - The sample standard deviation of the error (indicated values) for a number of consecutive automatic weighings of a load, or loads, passed over the load receptor, shall be expressed mathematically as:

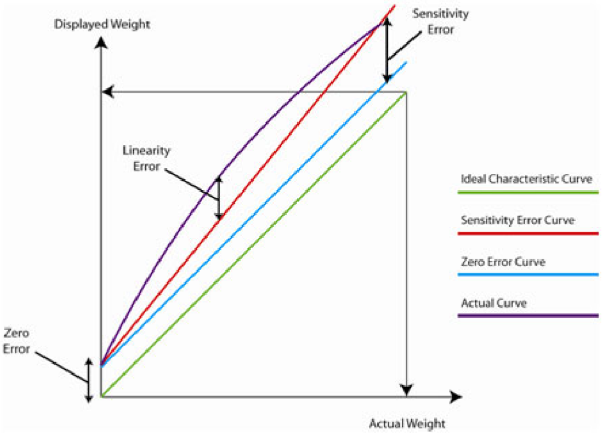
$$s = \sqrt{\frac{1}{n-1}\sum(x_i - \bar{x})^2} \quad \text{or} \quad s = \sqrt{\frac{1}{n-1}\left(\sum x_i^2 - \frac{(\sum x)^2}{n}\right)}$$

Where: x = error of a load indication

n = the number of loads

$\bar{x} = \frac{\sum x}{n}$

Scale Characteristic Curve



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