Weigh Module Systems

Applications
Designs
Calculations
Installations
Service

Weigh Modules
Load Cells

Weigh Module Systems Handbook

Engineering Guidelines for Customized Scales

METTLER TOLEDO

Introduction

This handbook is intended as a guide to selecting and applying METTLER TOLEDO weigh modules for process weighing applications. It provides the scientific data and accepted guidelines needed to help you design an accurate, reliable weighing system.

Warning

This publication is provided solely as a guide for individuals who have received technical training and are familiar with the technical manuals of the METTLER TOLEDO products.

This guide is not meant to replace the technical manual for various products.

Please review the specific technical manuals for detailed instructions and safety precautions before operating or servicing the various METTLER TOLEDO products.

METTLER TOLEDO reserves the right to make refinements or changes without notice.

Cautions and Warnings

This section presents a summary of cautions and warnings relating to the design through the use and routine maintenance of weigh modules and their scales. Many of these points are expanded upon in the sections that follow:

Initial Design
The scale and its support system must be designed by a locally qualified structural engineer; this includes the selection of weigh modules which become an integral part of the support structure. This is particularly critical if the scale is subject to extraneous forces due, for example to wind or seismic activity.
In selecting the load cell or weigh module Rated Capacity, consider all loads supported by the weigh modules including live load to be weighed, the dead dead load of the scale and the weight of supported ancillary equipment (such as mixers) and that of heating/cooling coils and fluid. Consider also the weight distribution if not evenly distributed on all weigh modules.
Warning: in hazardous areas in the EU, load cells, weigh modules and their options and accessories must be installed and used in accordance with Mettler Toledo installation instruction 30104376.
Compression weigh modules must be installed between two rigid frames or surfaces and the quantity must be 3 or greater.
Compression weigh module base plates cannot be mounted directly on wheels or casters.
Tension load cells and weigh modules must be installed with a safety backup, e.g., chains or rods, to prevent the scale from falling in case of any component failure.
External or on-board vibrations can affect scale performance.
Load cells and weigh modules can be damaged in wet, washdown and corrosive conditions.
Temperature changes can affect scale zero reading and sensitivity and can cause mechanical binding.
Extreme temperatures (high and low) can cause damage to a load cell, refer to load cell specification sheets.
If a scale is installed between 2 rooms at different pressures (e.g., a through-floor tank installation with a clean room above), this will affect scale accuracy if the pressure differential fluctuates.
Do not use hermetically sealed (welded) load cells in a vacuum as they may be damaged. Contact Industrial Support for assistance
Scale sensitivity will be affected if the scale level varies.

Installation and Service
Installation and service should be undertaken only by suitably qualified and trained personnel.
Prior to commencing any work, review with the customer the nature of the work to be performed and comply with the customer's policies and procedures for working in the vicinity of the scale equipment.
Confirm with the customer that the environment is safe for the installation or service work to be performed.
Warning: if working in a hazardous areas, do not install or perform any service on equipment before the area in which the equipment is located has been secured as non-hazardous by personnel authorized to do so by the responsible person at the customer's site.
Warning: in a hazardous areas, only the components specified in Mettler Toledo's manuals can be used. All equipment must be installed in accordance with the installation instructions detailed in Mettler Toledo's manuals. Incorrect or substitute components and/or deviation from Mettler Toledo instructions can impair the safety of the system and could result in bodily injury and/or property damage.
Warning: in hazardous areas in the EU, load cells, weigh modules and their options and accessories must be installed and used in accordance with Mettler Toledo installation instruction 30104376.
Cordon off the work area to restrict access. If working on a mezzanine floor or elevated platform, cordon off the area underneath to prevent injuries from falling objects.
Wear protective gear (e.g., gloves, hard hat, safety shoes) as appropriate to the product and as required on the particular work site.
Observe precautions for handling electrostatic sensitive devices, as appropriate.
Disconnect all power from equipment before installing, cleaning or servicing, including the removal of the fuse. Failure to do so could result in bodily harm and/or property damage.
Exercise care when making checks, tests, and adjustments that must be made with power on. Failing to observe these precautions can result in bodily harm.

Before connecting/disconnecting any internal electronic components or interconnecting wiring between electronic equipment, always remove power and wait at least 30 seconds. Failure to observe these precautions could result in bodily harm or damage to or destruction of the equipment.
Ensure proper equipotential grounding of the terminal, mounting accessories, and weigh modules.
Do not shorten the cable on analog load cells as this will affect their temperature compensation.
Failure to install load cells, weigh modules and assocaited parts in strict conformity with their instructions may result in malfunction, weighing inaccuracy, and may permanently damage the equipment.
In case of scale movement or oscillation, stop and isolate the scale before cleaning or making any adjustments to the weigh modules.
Be sure to block the scale when it is in the raised position while, for example, replacing a load cell---do not rely on the jacking device alone. The jack and block should stand vertically and securely contact the foundation and scale above. If the scale is not securely blocked, it could shift position resulting in bodily harm or property damage. Observe all appropriate safety procedures related to lifting and jacking.
Take care when lowering the scale onto the weigh modules to avoid any shock loads that could damage the weigh modules and/or their load cells.
Do not pass welding current through the load cells when welding on a scale, position the ground clamp as close as possible to the weld site and such that the welding current flows directly to the clamp without passing through any load cell. Shield the load cell cable from weld spatter. Never weld within 4 feet (1.2 meters) of any load cell, remove if necessary.
A wcompression weigh module's top and bottom plates must be supported sufficiently to avoid any deformation of these plates under load. You can fully support the base plate by grouting under it or by shimming at multiple locations. It is particularly important to support the top and base plates opposite the point of contact with the load cell and/or its receivers.
Remove all shipping/installation (e.g., SafeLock) components before calibration and weighing for the first time (does not apply if a weigh module kit is used as a deadstand).
Anti-lift bolts, where used, must be locked in position as described for the anti-lift function to operate correctly. Failure to do so may result in bodily harm or damage to or destruction of the equipment.
Tension weigh modules must be installed with a safety backup, e.g., chains or rods, to prevent the scale from falling in case of any component failure.
Prevent threaded connections on the tension weigh modules and their suspension rods from loosening by, for example, using jam nuts, double-nutting or by pinning or staking connections. Apply the same safety measures to the fastening of safety chains and rods.

Use and Routine Maintenance

Do not overload the scale by exceeding scale capacity.
Exercise care in loading a scale to avoid shock damage to the load cells; this can occur if heavy solid objects are dropped or lowered quickly onto it.
Wind and drafts acting on the underside, side, or top of a scale can affect weighing accuracy.
Build-up of debris under a scale or around the weigh module can seriously hamper scale performance and may damage the load cell. Remove debris regularly, especially any form of caking material.
Ice build-up under a scale or around the weigh module can seriously hamper scale performance and may damage the load cell. Avoid standing water, especially in areas where it can freeze.
Snow, ice, condensation or debris build-up on a scale will directly impact the weight reading and weighing accuracy. Pay particular attention to these points on outdoor storage tanks.
Changes in the mass of fluid in heating/cooling coils or jackets will directly impact the weight reading and weighing accuracy. Avoid the build-up of condensate in steam heated jackets.
In case of scale movement or oscillation, stop and isolate the scale before cleaning load cells and weigh modules.
Warning: in hazardous areas in the EU, load cells, weigh modules and their options and accessories must be installed and used in accordance with Mettler Toledo installation instruction 30104376.
Warning: in hazardous areas, avoid electrostatic charging during operation and maintenance. Keep the equipment away from processes that generate high charging potential such as electrostatic coating, rapid transfer of non-conductive materials, rapid air jets, and high pressure aerosols.
Warning: in hazardous areas, do not use a dry cloth to clean non-conductive parts of load cells, weigh modules and their accessories. Always use a damp cloth to gently clean these items.

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1. Introduction to Weigh Modules

A weigh module is a weighing device that consists of a load cell and the mounting hardware needed to attach the load cell to a platform, conveyor, tank, hopper, vessel or any object that is to become a scale. Typically, three or four weigh modules are used to fully support the full weight of the object. This effectively converts the object into a scale. A weigh module system must be able to (1) provide accurate weight data and (2) support the object safely.

There are two basic types of weigh modules: compression and tension.

Compression Weigh Modules

Compression weigh modules are suitable for most weighing applications. These modules can be attached directly to the floor, piers, or structural beams. The tank or other object is mounted on top of the weigh modules.

A typical compression weigh module is shown in Figure 1-1. It consists of a load cell, a top plate (which receives the load), a load pin (which transfers the load from the top plate to the load cell), and a base plate (which is bolted to the floor or other support surface). An anti-lift bolt prevents vessel tipping and provides lateral restraint. Three weigh modules in a triangular pattern is the minimum number required to fully support a scale; 4 weigh modules in a square or rectangular pattern is also common.

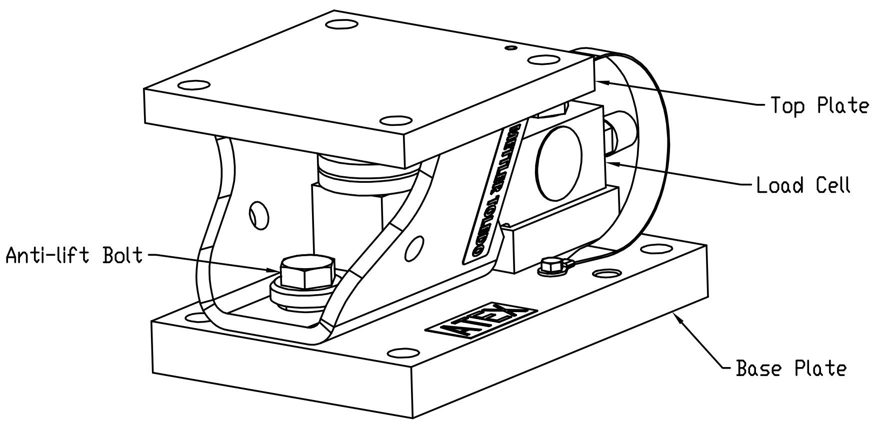


Figure 1-1: Compression Weigh Module

Replace from Picture 1 (1).pdf

Tension Weigh Modules

Tension weigh modules are used to create scales from tanks, hoppers or other objects that must be suspended from above, for example, from a building's superstructure or upper floor.

A typical tension weigh module is shown in Figure 1-2. It uses an S-shaped load cell that has threaded holes on both ends. A spherical rod-end bearing is screwed into each end and a clevis arrangement connects via threaded rods to the structure above and to the tank below. Typically three or more weigh modules are used to fully support the scale.

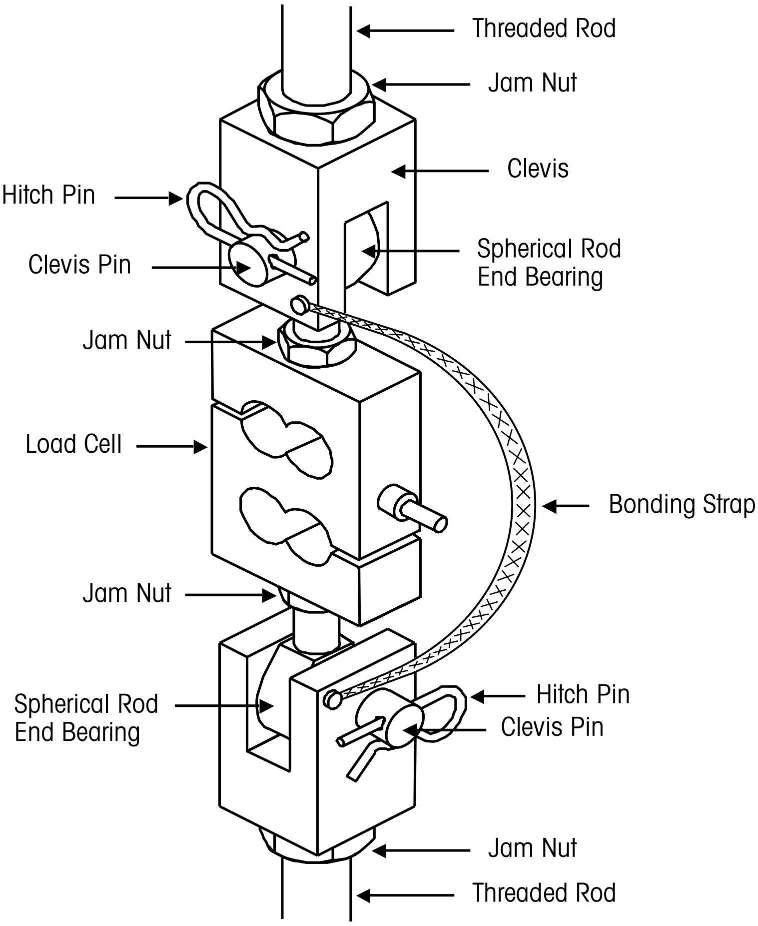


Figure 1-2: Tension Weigh Module

2. Weigh Module Applications

Weigh modules can be used to convert nearly any structure into a scale. They can be part of a structure's original design or can be added to an existing structure. This chapter describes the most common weigh module applications.

Tanks, Hoppers, Silos and Vessels

Tanks, hoppers, Silos and vessels are used for material handling in many industries. By attaching a system of weigh modules to one of these containers, you can weigh the contents accurately and reliably. This handbook uses "tank" as a generic term to refer to any tank, hopper, silo or vessel supported by weigh modules, but each is a specific type of container used for the purposes described below:

Tanks: A tank is usually a closed container used to store or process liquids, gases or free-flowing solids. Tanks range in size from small residential tanks for propane or heating fuel to large industrial tanks that can hold many tons of material. Figure 2-1 shows a tank supported by compression weigh modules; they can be horizontal or vertical and be symmetrical or non-symmetrical.

Hoppers: A hopper is a container that is open at the top and generally used to process solid materials in the form of powders or granules. It is generally used to dispense materials or collect ingredients for later processing. Hoppers tend to be smaller than tanks and are often suspended from a superstructure. Figure 2-2 shows a hopper supported by tension weigh modules.

Silos: A silo is a closed container similar to a vertical tank but used for the storage of solid materials in powder or granular form. Silos range in size and can be very large, up to several hundred tons. They are often positioned outdoors and used to supply the raw materials to an adjacent processing plant.

Vessels: A vessel is an elaborate tank with equipment to allow heating, cooling, mixing, or other processes. Chemical reactions often take place in vessels and therefore it must be possible to precisely weigh material additions.

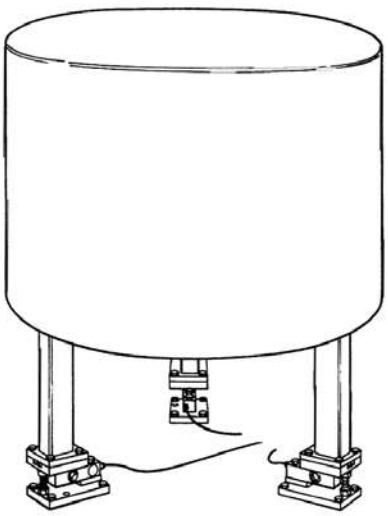


Figure 2-1: Vertical Tank Supported by Compression Weigh Modules

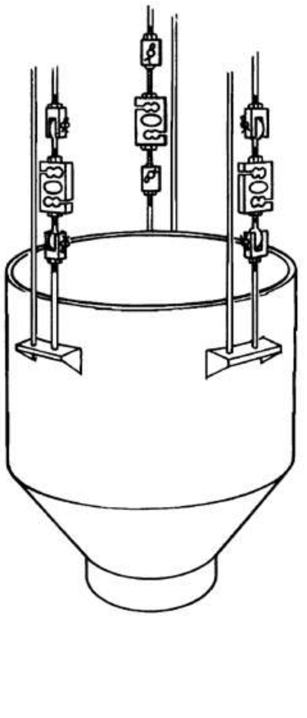


Figure 2-2: Hopper Supported by Tension Weigh Modules

Conveyors

To weigh objects that are transported on a conveyor system, mount a section of the conveyor on weigh modules (see Figure 2-3). Because the objects being weighed on a conveyor are usually in motion, these applications require a weigh module capable of withstanding high horizontal shear loads while still delivering repeatable weighments. METTLER TOLEDO self-aligning weigh modules allow the conveyor's weighing section to absorb shocks by moving back and forth when subjected to horizontal shear loads. But the load cell's self-restoring suspension system always returns the conveyor to its "home" position to ensure repeatable weighing.

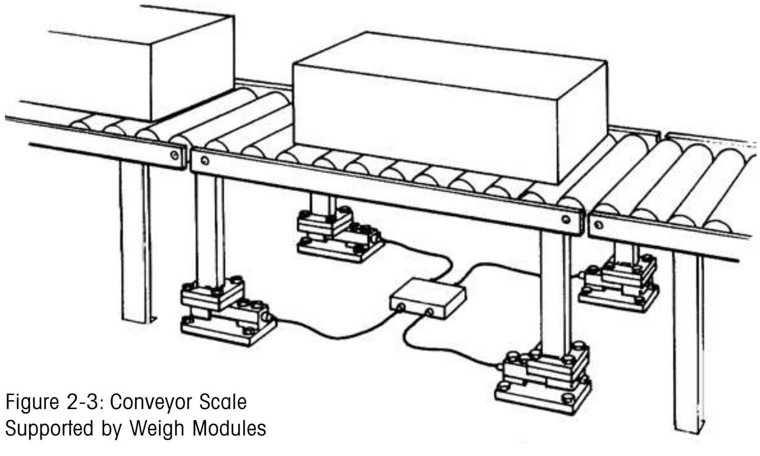


Figure 2-3: Conveyor Scale Supported by Weigh Modules

Platform Scales

There is a wide variety of platform scales available as standard products but sometimes it is necessary to construct a special-purpose platform to suit a particular application; this may be done with weigh modules, as shown in Figure 2-4.

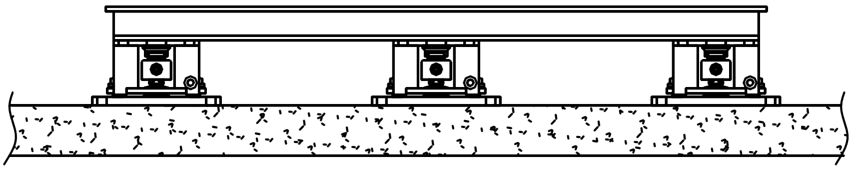


Figure 2-4: Platform Scale Supported by Weigh Modules

Mechanical Scale Conversions

There are two ways to convert older mechanical lever scales (see Figure 2-5) for electronic weighing. The first method is a lever conversion. It involves adding an S-Cell tension weigh module while retaining the levers and weighing platform from the existing mechanical scale. The second method is a lever replacement. It involves removing the levers and adding compression weigh modules beneath the existing weighing platform.

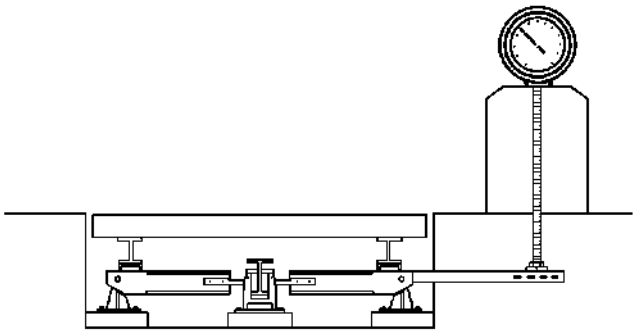


Figure 2-5: Mechanical Scale

Lever Conversion

A lever conversion retains the mechanical scale's dial head, so that the scale can be used for both electronic and mechanical weighing. An S-Cell tension weigh module is inserted into the existing steelyard rod located in the column of the dial head. The dial head is locked out to allow the S-Cell to sense the tension load applied by the transverse lever that extends from the scale pit. In case of a power failure or failure of the electronics, the operator can revert to fully mechanical operation by unlocking the dial head. Figure 2-6 shows a lever conversion.

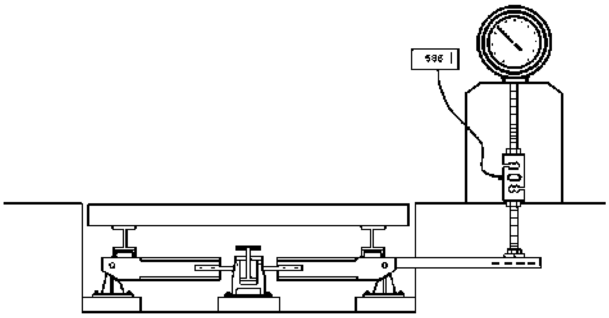


Figure 2-6: Electro-Mechanical Scale

How to determine the load cell capacity in lb [kg] needed for a conversion:

- Determine the Initial Tension Load in lb [kg] in the steelyard rod resulting from the dead load of the platform.
- Determine the Capacity in lb [kg] of the existing scale.
- Determine the Multiple of the lever system.

Insert the variables listed above into the following formula:

$$\text{Load Cell Capacity} = \text{Initial Tension Load} + \frac{\text{Capacity}}{\text{Multiple}}$$

This is the absolute minimum load cell capacity that could be used, multiply this by a safety factor, as discussed further in chapter 7, Tension Weigh Modules.

Sizing Tips

Initial Tension Load: One way to determine the initial tension load in the steelyard rod is to use a lever to raise the steelyard rod. Attach a lifting point, such as a clamp, to the steelyard rod and make sure it is tightened securely. The tension load is the weight that must be applied to the free end of the lever to just raise the steelyard rod, corrected using a multiplier based on the position of the lever's fulcrum (see Figure 2-7). For example, if the fulcrum is 2 inches [5cm] from the end of the lever that is placed under the lifting point and 20 inches [50cm] from the free end, multiply the load in lb [kg] that must be added to the free end of the lever by 10 to determine the tension load in lb [kg].

Capacity: The capacity of the scale should be marked on the scale's data plate, convert this to lb [kg] if necessary.

Multiple: You can determine the multiple of a lever system by attaching a known test weight to the steelyard rod of the empty scale. The multiple will be the weight change shown on the dial divided by the value of the test weight. For example, if the weight change on the dial is 2,000 lb [1000 kg] when a 5 lb [2.5 kg] test weight is hung from the steelyard rod, then the multiple is 400.

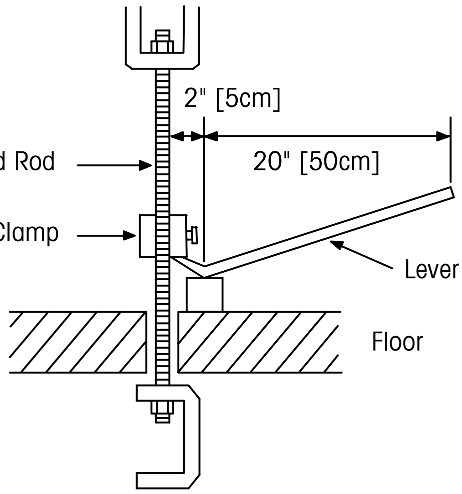


Figure 2-7: Using a Lever to determine initial tension load in a steelyard rod.

Lever Replacement

A lever replacement eliminates the mechanical scale's levers and dial head. The existing weigh platform can be modified to accept compression weigh modules. This conversion results in a fully electronic scale (see Figure 2-8).

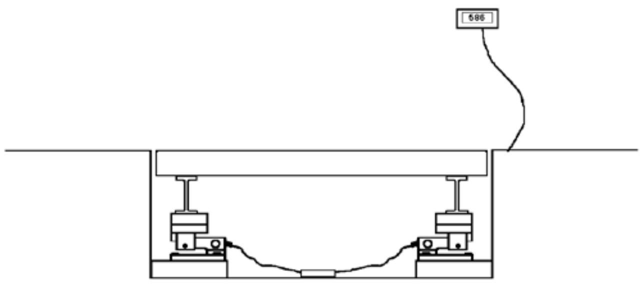


Figure 2-8: Fully Electronic Scale

3. Weigh Module General Considerations

Compression versus Tension Weigh Modules

There are two basic types of weigh modules:
Compression weigh modules are designed so that a tank or other structure can be mounted on top of the weigh modules. **Tension** weigh modules are designed so that a tank or other structure can hang from the weigh modules.

Whether you use compression or tension weigh modules often depends on the specific application. Table 3-1 provides an overview of general design considerations affecting the choice of weigh modules.

Design Consideration	**Compression Weigh Modules**	**Tension Weigh Modules**
Floor Space	Requires enough floor space to accommodate tank size. Might require buffer space around tank.	Requires no floor space and can be suspended to allow free movement beneath tank.
Structural Restrictions	Weak floors might require additional construction or a special installation to accommodate weight of filled tank.	Weak overhead supports/ceilings might require additional construction or special installation to accommodate weight of filled tank.
Weight Limit	Generally unlimited. Even load distribution is inherent with three vessel supports, and is increasingly difficult to achieve as the number grows beyond four.	Tension weigh modules are available up to 20,000 lb [10t]. This and structural considerations limit tension system capacity.
Load Cell Alignment	Designs may vary and must consider floor deflection, available support beams, and tank size, shape, and condition.	Cell alignment will not vary significantly because tension rods and other support equipment tend to accommodate most deflections.

Table 3-1: Comparison of Compression and Tension Weigh Modules

Static versus Dynamic Loading

When selecting weigh modules for an application, it is important to consider how the load will be applied to the weigh modules. Most weigh module applications on tanks, hoppers, silos and vessels are subject to static loading. With static loading, little or no horizontal shear force is transmitted to the weigh modules. Applications such as conveyors, pipe racks, mechanical scale conversions, and scales with high-powered mixers or blenders are subject to dynamic loading. With dynamic loading, the way in which products are placed on a scale or processed transmits horizontal shear forces to the weigh modules. Refer to Chapter 6, Compression Weigh Modules, for a discussion of the types of weigh module suspensions and their application parameters.

How Many Weigh Modules?

For an existing installation, the number of weigh modules is determined by the number of existing supports. If a tank has four legs, you will need to use four weigh modules.

For new installations a three-point support system is preferred as correct load distribution on the weigh modules is assured. If wind, fluid sloshing, or seismic loading is a factor, the tank might require four or more supports for additional stability and protection against tipping.

Most tank scale applications use either three or four weigh modules. METTLER TOLEDO indicators can sum the outputs from four, eight or more weigh modules, but achieving even weight distribution and shift adjustment become increasingly difficult beyond four.

To calculate the required capacity for each weigh module, divide the gross capacity of the system by the number of supports. A safety factor should be applied to the gross capacity in case the weight is underestimated or distributed unevenly. The procedure for sizing weigh modules is explained in the Chapter 6, Compression Weigh Modules, and chapter 7, Tension Weigh Modules. Environmental factors such as seismic and wind loading can also affect the capacity of the weigh modules required for an application, see Chapter 4, Weigh Module Environmental Considerations.

Analog or POWERCELL® load cells?

Today there are two types of weigh module systems being offered: Systems equipped with analog load cells and systems with digital POWERCELL® load cells. POWERCELL® load cells incorporate the A/D conversion electronics and provide digital CAN bus output. Measurement errors caused by temperature, creep, non-linearity, hysteresis, etc. are compensated digitally in POWERCELL® and allow for better accuracy and tighter tolerances.
An analog weigh module system requires:

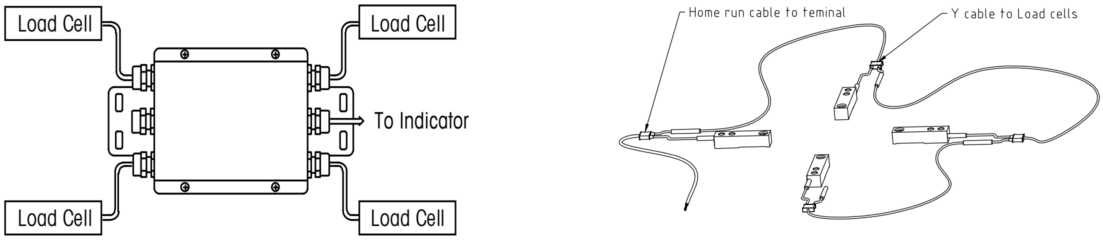
- Weigh modules with analog load cells and their cables
- Junction box
- Home-run cable to the Terminal.

In such a system, cables and junction boxes have a significant impact on the very low signals, and the system must be calibrated as a whole. Any change or replacement means a full re-calibration of the system. In addition to this, analog systems are prone to Electro-magnetic Interference (EMI).
A POWERCELL® weigh module system consists of:

- Weigh modules with POWERCELL® load cells
- Separate cables
- Termination resistor for the CAN bus.

The junction box is eliminated from the system as potential error source. The weighing information is provided digitally, not as a very low analog voltage, and hence the cables have no influence on the system performance. Cables can be replaced any time without needing a re-calibration.

POWERCELL® weigh module systems also offer continuous monitoring of the load cells, for overload, poor communication between modules, out-of-symmetry errors, and out-of-range temperatures. Load cell failure is detected immediately and the operator and/or control system notified immediately. In addition to this, POWERCELL® load cells offer higher accuracy, up to OIML C10 class.



Analog System
(1-4 cells)

POWERCELL® System

Figure 3-1: Analog and POWERCELL Systems

Field Calibration

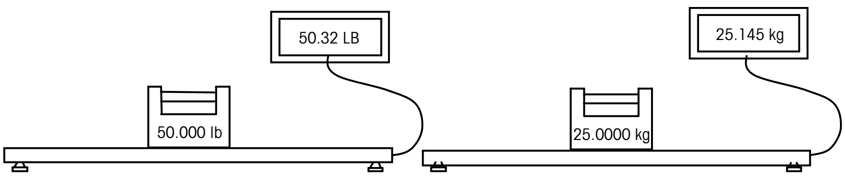
Another consideration is how the weigh module system will be calibrated. If you are adding weigh modules to an existing tank, you might need to modify the tank so that you can hang certified test weights from it. At a minimum, the tank should be able to support test weights equal to 20% of the net product weight (programmed capacity). Several methods of field calibration are described in Chapter 8, Weigh Module System Calibration.

Weighing System Performance

Accuracy, resolution, and repeatability are basic concepts used to measure a weighing system's performance. Accuracy is how close the reading on a scale's indicator is to the actual weight placed on the scale. A scale's accuracy is usually measured against a recognized standard, such as NIST Certified Test Weights.

Resolution is the smallest weight change that a digital scale can detect. Resolution is measured in increment size, which is determined by the capabilities of the load cells and digital indicator. A digital weight indicator may be able to display a very small increment size, such as 0.01 lb [5g]; however, that does not mean the system is accurate to 0.01 lb [5g].

Figure 3-2 helps to show the difference between accuracy and resolution. Although the indicator has a resolution of 0.01 lb [0.005 kg], the weight reading is inaccurate by 0.32 lb [0.145 kg]. Resolution is determined by an indicator's electronic circuitry. Many of today's industrial indicators can resolve a load cell's signal into 1,000,000 internal divisions and can actually display 100,000 divisions. The displayed resolution is determined by how the indicator is configured. But displaying an increment size does not make a scale accurate to that increment.



Repeatability is a scale's ability to display a consistent weight reading each time the same weight is placed on the scale. It is especially important for batching and filling applications, which require that the same amount of a material be used for each batch. Repeatability and accuracy go hand in hand. You can have a repeatable system that is not accurate, but you cannot have an accurate system unless it is repeatable.

The following factors can influence the accuracy and repeatability of a weighing system. They are discussed in detail later in this handbook.

- Environmental Factors: Wind, Seismic Forces, Temperature, Vibration
- Weigh Module System Support Structures
- Tank and Vessel Design
- Piping Design (Live-to-Dead Connections)
- Load Cell and terminal Quality
- Total Load Cell Capacity
- Calibration
- Operational / Process Factors

Determining System Accuracy and Repeatability

Experience has shown that a tank scale fully supported by weigh modules on a firm foundation can be accurate to within 0.1% of the applied load (the weight placed on the scale). When this type of scale is calibrated correctly, it will give an accurate reading of the weight placed on it. Ideally, the percentage of total weight capacity should equal the percentage of total counts (increments). This relationship is illustrated in Figure 3-2.

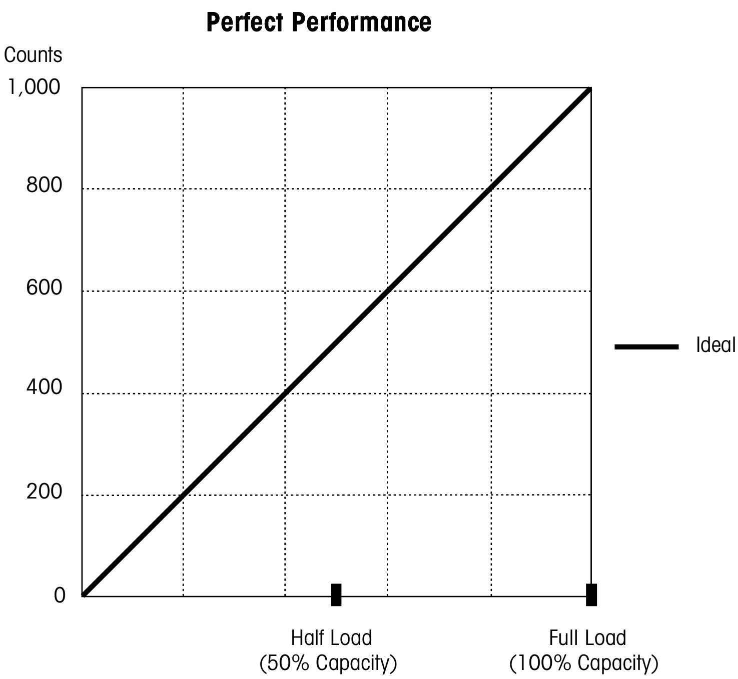


Figure 3-3: Ideal Weight Capacity vs. Counts

If a scale has 1,000 counts and a total capacity of 5,000 lb [2000 kg] then each count should equal 5 lb [2 kg]. When a 2,500 lb [1000 kg] weight is placed on the scale, there should be 500 counts. With a 5,000 lb [2000 kg] weight, there should be 1,000 counts. This relationship should not change regardless of whether weight is being added to or removed from the scale.

When a scale is not calibrated correctly, this ideal relationship does not hold true. There are four main types of errors that cause inaccurate weighing:

- Calibration Errors
- Linearity Errors
- Hysteresis Errors
- Repeatability Errors

Calibration Errors

Some errors are caused because the weighing equipment is not calibrated correctly. When there is a calibration error (see Figure 3-3), the counts-to-load ratio is still a straight line, as it was in the ideal scale. But the line does not reach 100 percent of the counts at full load. The relationship between the weight and the counts is linear but not correct. This is usually caused by an error in the electrical calibration of the scale and can be corrected by recalibrating the scale.

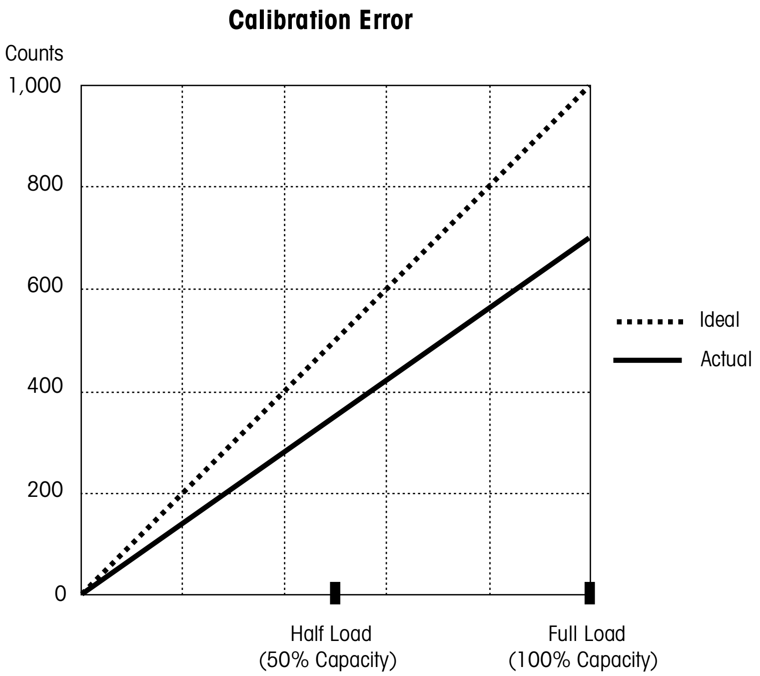


Figure 3-4: Calibration Error

Linearity Errors

Linearity is a scale's ability to maintain a consistent counts-to-load ratio (a straight line on the graph) as load is applied to the scale. When there is a linearity error, a scale reads correctly at zero and at full load capacity but incorrectly in between those two points (see Figure 3-4). The weight indication can either be higher than the actual weight (as shown in the graph) or lower than the actual weight.

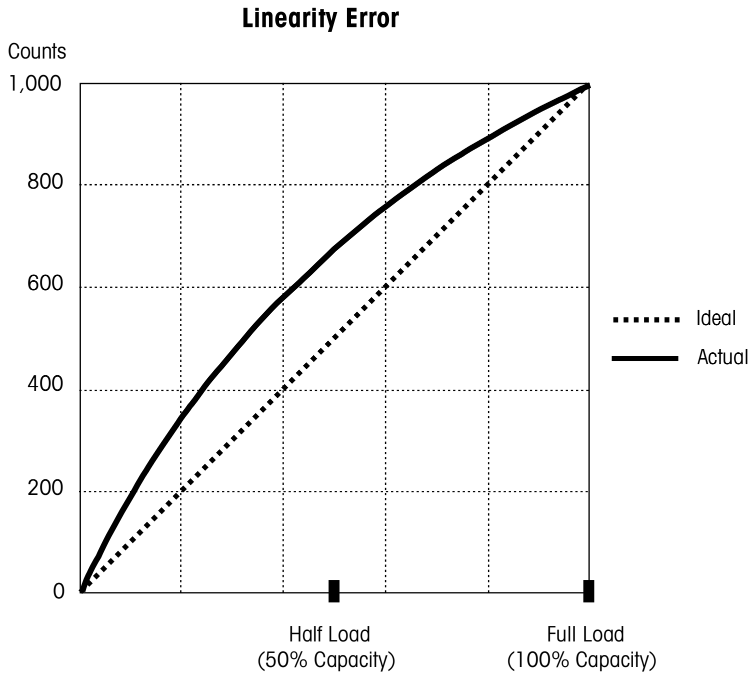


Figure 3-5: Linearity Error

Hysteresis Errors

Hysteresis is the maximum difference in scale reading for the same applied load, one reading obtained by increasing the load from zero and the other by decreasing the load from full load. Figure 3-5 shows a typical hysteresis error. The scale is accurate at zero and at full load. When weight is gradually added to the scale, the curve is below the straight line displaying readings that are too low. After reaching full load the weight is gradually decreased, the curve is above the straight line displaying readings that are too high. Hysteresis is the maximum difference between the loading and unloading curves; it occurs at half load in this example. You should take steps to minimize linearity and hysteresis errors in batching, filling, and counting scale applications, especially when the full range of the scale is used.

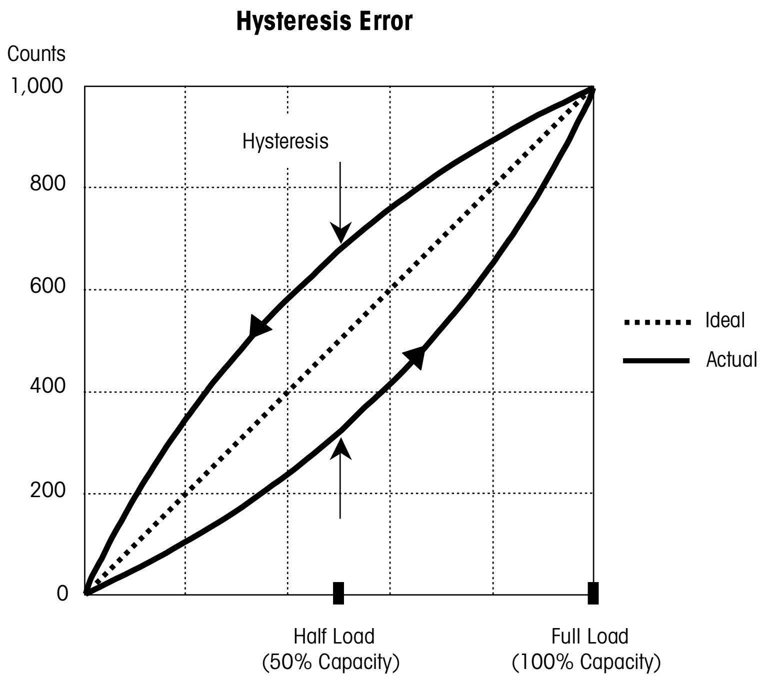


Figure 3-6: Hysteresis Error

Repeatability Errors

Repeatability is a scale's ability to repeat the same reading when the same weight is applied and removed several times under identical environmental conditions. It is the maximum difference between readings and is expressed as a percentage of applied load. For example, suppose the same 5,000 lb [2500 kg] weight is placed on a 5,000 lb [2500 kg] scale 10 times, with 5,001 lb [2500.5 kg] being the highest reading and 5,000 lb [2500 kg] being the lowest. The repeatability error is 1 lb [0.5 kg} or 0.02% (1/5,000) of the scale's applied load (A.L). Note that repeatability error scales with applied load, halve the applied load and the repeatability error should halve.

What Kind of Accuracy Can You Expect in the Real World?

Scale system accuracy depends on the quality of the load cells used. The best you can expect from a scale system is to approach the performance ratings of the load cells alone. Here are typical performance ratings for quality load cells:

- Non-linearity: ± 0.01% of Rated Capacity (R.C.)
- Hysteresis: ± 0.02% of Rated Capacity (R.C.)
- Combined error: ± 0.02% to 0.03% of Rated Capacity (R.C.)

Combined error is the error due to the combined effect of non-linearity and hysteresis. Figure 3-6 shows load cell combined error as an error band from zero load to rated capacity. All weight readings should fall within this £error band. Under ideal conditions, a scale system's accuracy can approach or exceed the accuracy of the individual load cells in the system (0.02% of system capacity or better). In the real world, however, accuracy is affected by environmental and structural factors such as vibration, temperature, live-to-dead connections, piping, and module support integrity.

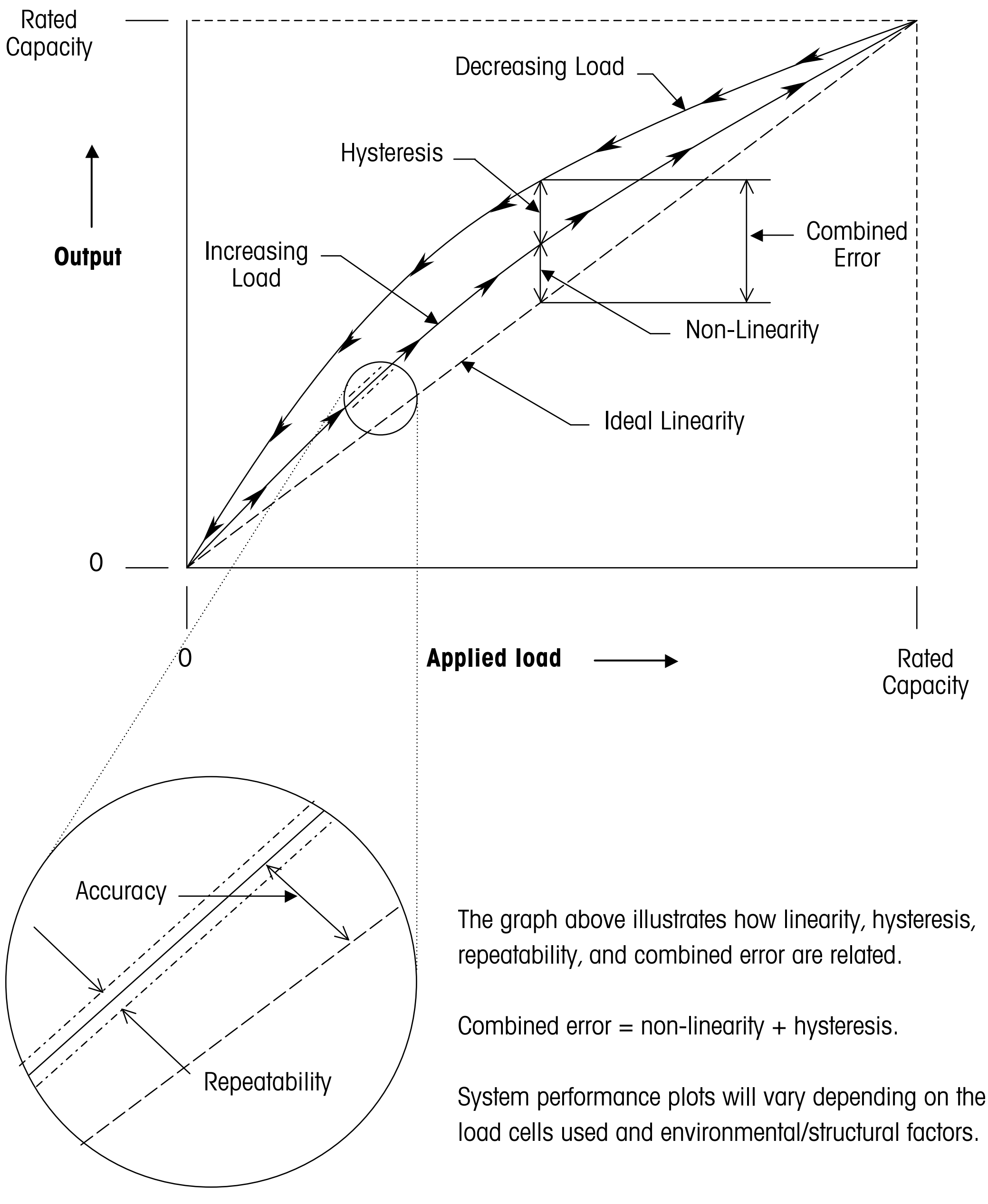
Predicting System Accuracy

A tank scale's accuracy is determined by a combination of factors, including the indicator, load cells, mounting hardware, tank design, foundation, and environmental influences. Different applications require different levels of weighing accuracy. A precision batching or filling process requires greater accuracy than a bulk storage operation. Table 3-2 specifies four levels of weighing accuracy and lists the factors that will affect a tank scale's ability to meet those accuracy levels. Following the recommendations listed in the table will help ensure that a tank scale provides the desired level of accuracy.

METTLER TOLEDO has developed a software tool (Weighing Component Selector) which calculates the uncertainty that can be achieved by a system of weighing components that can include 1 or more load cells or weigh modules, a terminal, junction box(es) and AUX cable (used to connect between multiple junction boxes), as appropriate. The calculation Report can be provided by a METTLER TOLEDO sales representative. The Weighing Component Selector considers the specifications of the selected weighing components, the scale's environmental conditions and the scale's method of use. The specifications considered are Temperature Effect on Min. Dead Load Output (zero), Temperature Effect on Sensitivity, Repeatability, Combined Error (combined effect of Non-Linearity and Hysteresis), Creep, and Display Rounding. It does not consider scale design, installation, calibration or off-center load errors. In particular, it does not consider the effects of piping or other attachments to the scale which can severely affect uncertainty. The calculation is based on a 95% (2 sigma) confidence level.

System Accuracy Summary

True system accuracy can be determined only by testing and validating after the entire system has been installed. Once all the piping and system components are attached, "exercise" the vessel by adding test weights or other material up to the full capacity of the scale. That will eliminate any built-up stresses and allow the system to settle. Once the system has settled, run several tests from zero to full capacity to determine resulting system performance. Starting at a no-load condition, apply known weights in convenient steps up to full system capacity. Record the indicated weight at each step. Then take weight readings at the same intervals as weight is removed from the system. To determine actual system error, compare the indicated weight readings with the actual weights applied to the scale.



The graph above illustrates how linearity, hysteresis, repeatability, and combined error are related.

Combined error = non-linearity + hysteresis.

System performance plots will vary depending on the load cells used and environmental/structural factors.

Figure 3-7: Sample Load Cell System Performance Graph

System Parameters				
Accuracy	Ultra Precision	High Precision	Medium Precision	Level Detection
Accuracy Level	Best	Better	Good	Fair
System Accuracy (% system capacity)*	0.008 to 0.013	0.013 to 0.025	0.025 to 0.5	Greater than 0.50
Load Cell Utilization (% rated capacity)*	≥ 50	≥ 30	≥ 30	≥ 20
Application Type	Reactor vessels for formulation, blending, batching, precision filling	Holding tanks, hoppers, conveying systems, batching, filling	Holding tanks, hoppers, conveying systems	Bulk storage tanks for raw materials and commodities
Scale Equipment Parameters				
Load Cell Certification	OIML: C10	OIML: C6 NTEP: 10,000d III M	OIML: C3 NTEP: 5,000d III M	Approved or not approved
Weigh Module Load Suspension	Self-aligning	Self-aligning or sliding	Self-aligning, sliding, or rigid	Self-aligning, sliding, or rigid
Dead Stand or Dummy Load Cell	None	None	None	Only for liquids or gases
Installation Parameters				
Tank Characteristics	Provision for test weights, rigid mounting supports	Provision for test weights, provision for hydraulic calibration, rigid mounting supports	Provision for test weights, provision for hydraulic calibration, rigid mounting supports	Rigid mounting supports
Inlet and Outlet Piping	Flexible only	Flexible only	Flexible and rigid	Flexible and rigid
Foundation	Rigid and isolated from surrounding influences, uniform deflection	Rigid and isolated from surrounding influences, uniform deflection	Rigid with uniform deflection	Rigid with uniform deflection
Environmental Parameters				
Load Cell Temperature Range	Within load cell nominal limits	Within load cell nominal limits	Within load cell nominal limits	Within sensor operating limits
Vibration	None	Limited, use isolation pads and instrument filtering	Limited, use isolation pads and instrument filtering	Use isolation pads and instrument filtering as required
Wind and Air Currents	Indoor installation recommended	Up to weigh module limits	Up to weigh module limits	Up to weigh module limits
Calibration Procedure				
Recommended Procedure	Test weights, material substitution	Test weights, RapidCal™ material substitution, material transfer	Material substitution, RapidCal™ material transfer	Material transfer, RapidCal™, electronic
CalFREE™ Calibration	No	Not recommended	Yes, when there is no other choice	Yes
Weigh Modules				
Models	Self-aligning	Self-aligning, sliding, or tension	Self-aligning, sliding, rigid, or tension	Combination of live and dead weigh modules or dead stands
Material	Stainless steel recommended	Carbon steel, stainless steel	Carbon steel, stainless steel	Carbon steel, stainless steel
Indicators				
TraxDSP™ Filtering for Stability	Recommended	Recommended	As required	As required
Predictive Maintenance	Recommended	Recommended	Recommended	As required

* System capacity is the scale capacity programmed into the indicator. Rated capacity (R.C.) is the capacity of the load cells supporting the scale. Load cell utilization is the percentage of each load cell's rated capacity used when the scale is loaded from zero to system capacity. Example: If a scale with a capacity of 5,000 lb [2500 kg] pounds is supported by four 2,500 lb [1250 kg] load cells, the load cell utilization is 50% of rated capacity.

Table 3-2: Tank Weighing Accuracy for Weigh Module Systems

Determining System Resolution

Non-transactional Process Weighing

The ability of a combination of load cells and indicator to give the desired system resolution or increment size can be determined by the following formula:

$$\text{Signal Strength (Microvolts per Increment)} = \frac{\text{Desired Increment Size} \times \text{Load Cell Output (mV/V)*} \times \text{Excitation Voltage} \times 1{,}000}{\text{Individual Load Cell Capacity} \times \text{Number of Load Cells}}$$

*Most METTLER TOLEDO load cells have an output of 2 mV/V.

Enter the desired increment size into the formula, along with the load cell and indicator parameters, using the same units for weight throughout. If the signal strength (microvolts per increment) exceeds the minimum allowed for the indicator, the system should be able to deliver the desired resolution.

Example 1:

Suppose a tank scale has four 5,000 lb load cells (2 mV/V) attached to an indicator that has an excitation voltage of 15 VDC and a minimum of 0.1 microvolt per increment, and a maximum of 100,000 displayed increments. You want to be able to weigh up to 15,000 lb with 2 lb increments (7,500 displayed increments). Use the formula to determine the required signal strength:

$$\frac{2\ \text{lb} \times 2\ \text{mV/V} \times 15\ \text{VDC} \times 1{,}000}{5{,}000\ \text{lb} \times 4} = 3.0\ \text{microvolts per increment}$$

The minimum allowable signal strength for the indicator is 0.1 microvolt per increment. Since the 3.0-microvolt per increment signal derived from the formula is above this 0.1-microvolt minimum, you should be able to display 2 lb increments.

Example 2:

Suppose a tank scale has four 1100 kg load cells (1.94 mV/V) attached to an indicator that has an excitation voltage of 5 VDC, a minimum of 0.1 microvolt per increment, and a maximum of 100,000 displayed increments. You want to be able to weigh up to 1000 kg with 0.2 kg increments (5000 displayed increments). Use the formula to determine the required signal strength:

$$\frac{0.2\ \text{kg} \times 1.94\ \text{mV/V} \times 5\ \text{VDC} \times 1{,}000}{1100\ \text{kg} \times 4} = 0.44\ \text{microvolts per increment}$$

The minimum allowable signal strength for the indicator is 0.1 microvolt per increment. Since the 0.44 microvolt per increment signal derived from the formula is above this 0.1-microvolt minimum, you should be able to display 0.2 kg increments.

Legal-for-Trade Transactional Weighing

If you are using a scale to buy and/or sell materials by weight, the resolution or increment size is limited by the scale's approval. The following section explains the industry standards for legal-for-trade applications and the limits that they place on a scale's resolution.

Industry Standards (Legal-for-Trade)

There are several organizations that set standards for the scale industry and provide type evaluation to ensure the accuracy of scales. In the United States, type approval is given by the National Type Evaluation Program (NTEP), which is administered by the Office of Weights and Measures of the National Institute of Standards and Technology (NIST). In Europe, type approval is given by the European Union (EU) Member States according to recommendations set by the Organisation Internationale de Métrologie Légale (OIML).

United States Standards

NIST is part of the United States Department of Commerce. It sponsors the National Conference on Weights and Measures (NCWM), an association of industry representatives and federal, state, and local officials. This organization adopts uniform laws and regulations recommended by NCWM members, and it publishes those regulations in NIST Handbook 44. Adopted by most states and localities, NIST Handbook 44 is the official listing of specifications, tolerances, and other technical requirements for weighing and measuring devices.

Type evaluation is the procedure used to test a particular type (or model) of weighing device. NTEP tests a sample of each model in a laboratory or in the field. If the model is produced in various sizes and capacities, NTEP will evaluate a selection of these based on the availability of sizes and capacities, the number of divisions, and the smallest division size. If the tests show that the scale(s) complies with the applicable technical requirements of NIST Handbook 44, NTEP issues a Certificate of Conformance for that model of scale.

A Certificate of Conformance indicates that the particular scale tested by NTEP met NIST Handbook 44 requirements, not that all scales produced meet the requirements. It is the scale manufacturer’s responsibility to make sure that every scale of a certified model meets the published specifications. Whether or not all models of an NTEP-certified scale conform to NIST Handbook 44 specifications is solely up to the discretion of the manufacturer. METTLER TOLEDO has procedural controls in place to guarantee that every scale is produced according to the same specifications.

NIST Handbook 44 defines both acceptance and maintenance tolerances. Acceptance tolerances must be met when the scale is first certified by NTEP and when the scale is first put into service. Maintenance tolerances are twice as large as acceptance tolerances and apply after the scale has been in service for a specified period of time. Figure 3-7 shows NIST Handbook 44 acceptance tolerances for Class III scales.

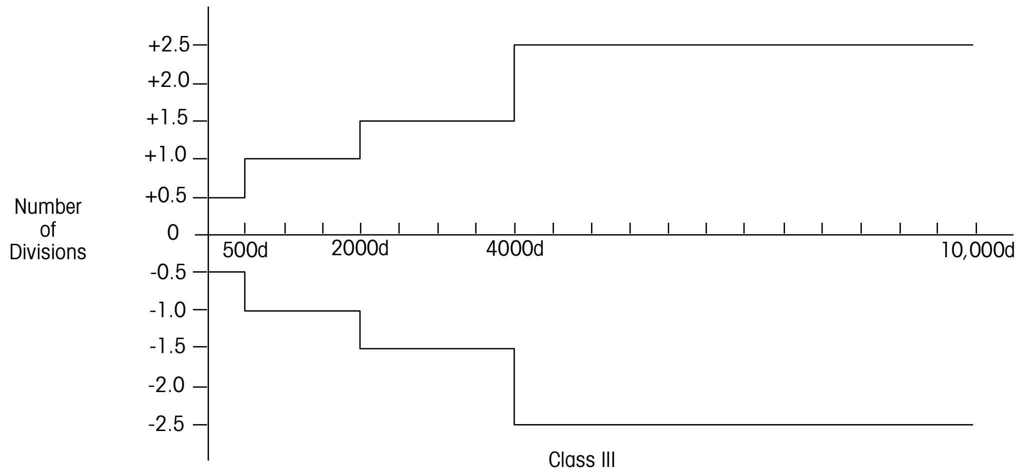


Figure 3-8: Handbook-44 Acceptance Tolerance Table

The divisions on the vertical axis represent permissible error (the specified limits). The horizontal axis shows the number of divisions that corresponds to the actual weight on the scale. For example, if a weight corresponding to 1,000 divisions is placed on the scale, the indicator must read 1,000 divisions ±1.0 division. If the weight corresponds to 3,000 divisions, the tolerance is ±1.5 divisions. At full capacity, the tolerance is ±2.5 divisions. In order to be certified, a scale must perform within the specified limits over a temperature range of 54°F [30°C]. Typically, scales are designed to perform within the specified limits over the larger temperature range of 14°F to 104°F [-10°C to +40°C].

It is important to understand how tolerances relate to the accuracy of a scale. If a scale is rated as 5,000 divisions, that does not mean it is accurate to 1 part in 5,000. One part in 5,000 should never be used to express accuracy because, according to Handbook-44 tolerances, 2.5 parts of error are allowed at 5,000 divisions.

The accuracy of a scale can also be described as a percentage of applied load accuracy. In Figure 3-8 the dashed line indicates a performance of 0.1% of applied load accuracy, compared with Handbook-44 Class III acceptance tolerances. A 0.1% (or ±0.05%) applied load accuracy roughly corresponds with the NIST Handbook 44 chart through 5,000 divisions. Notice, however, that the line indicating 0.1% applied load accuracy falls outside the acceptance tolerance between 3,000 and 4,000 divisions and above 5,000 divisions. Because the 0.1% applied load accuracy method fails to meet tolerance standards at those points, it should be used only as an approximation of the acceptance tolerances. NIST Handbook 44 or local Weights and Measures guidelines should always be used as the actual acceptance tolerances.

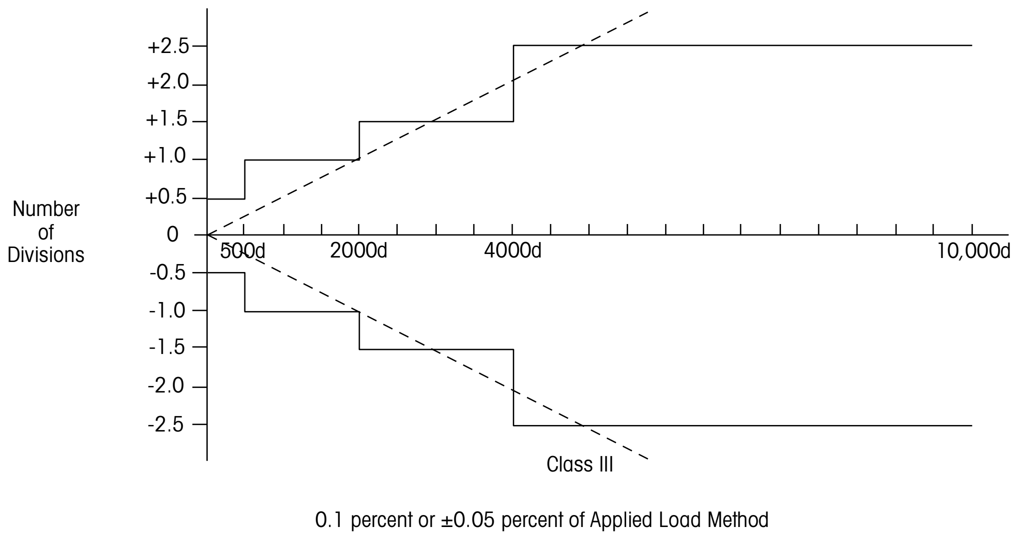


Figure 3-9: Handbook-44 Acceptance Tolerance Table (Percent Applied Load Method)

International Standards

Although NTEP certification is widely accepted in the United States, it is not a worldwide standard. When selling products outside of the United States, you should understand and follow the local standards. Some common standards include the Measurement Canada standard that is used in Canada and the Organisation Internationale de Métrologie Légale (OIML) standard adopted by the European Economic Community.

OIML is an independent international organization that develops standards for adoption by individual countries. Its main task is harmonizing the regulations and metrological controls applied by the national metrological services in the countries that are OIML members. There are two main types of OIML publications:

- **International Recommendations** (OIML R) are model regulations that establish the metrological requirements for scales, as well as requirements for specifying methods and equipment used to check a scale's conformity. OIML member countries are responsible for implementing the recommendations.
- **International Documents** (OIML D) provide information to help improve the work of the national metrological services.

A scale with NTEP certification does not automatically meet OIML standards. Several European testing labs (such as NMi, BTS, and PTB) conduct performance tests to verify whether the equipment meets OIML standards and is capable of performing its intended functions. OIML has its own set of accuracy classes and acceptance tolerances. Instruments are classified according to absolute and relative accuracy.

- Verification scale interval (e) represents absolute accuracy.
- Number of verification scale intervals (n = Max Capacity/e) represents relative accuracy.

The accuracy classes for instruments and their symbols are listed below:

Accuracy Class	**Symbol**
Special Accuracy	I
High Accuracy	II
Medium Accuracy	III
Ordinary Accuracy	IIII

Figure 3-9 shows OIML class III acceptance tolerances, and Figure 3-10 compares those with NIST Handbook 44 class III tolerances. Again, the vertical axis represents the permissible error and the horizontal axis represents the number of divisions that corresponds to the actual weight on the scale. Note that OIML acceptance tolerances are identical to those in NIST Handbook 44 from 0 to 4,000 divisions. At 4,000 divisions, the NIST acceptance tolerance increases from ±1.5 divisions to ±2.5 divisions, while the OIML acceptance tolerance remains at ±1.5 divisions up to 10,000 divisions.

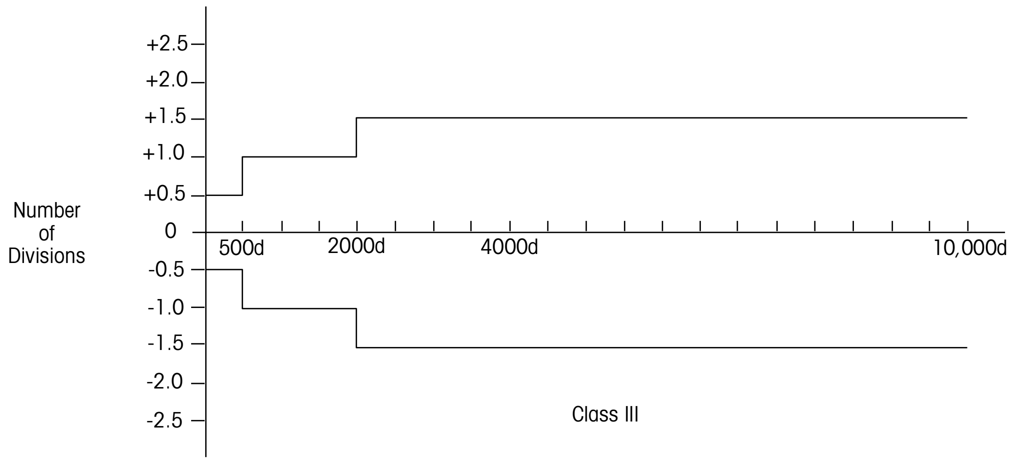


Figure 3-10: OIML Acceptance Tolerance Table

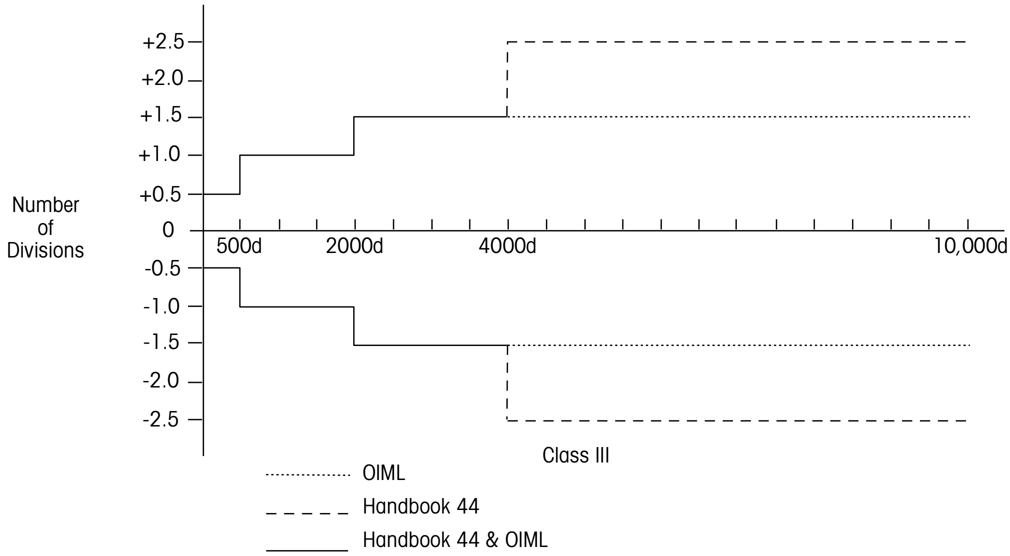


Figure 3-11: Handbook-44/OIML Acceptance Tolerance Overlay

In order to be classified as "Legal for Trade," a scale must meet OIML acceptance tolerances. The scale's weight readings must be within the specified limits, relative to the number of divisions (or increments) that correspond to the actual weight used. For example, if a weight that corresponds to 5,000 divisions is placed on the scale, then the indicator must display 5,000 divisions ±1.5 divisions in order to meet OIML acceptance tolerances. In order for the same scale to meet NIST acceptance tolerances, the indicator could display 5,000 divisions ±2.5 divisions. The wider acceptance tolerance allowed by NIST was originally intended to approximate the 0.1% of applied load method.

To meet OIML standards, a scale must satisfy all requirements and perform within the calibration tolerance limits.

Under EC Weights and Measures regulations, there is a difference between the concepts of a "test certificate" and an "approval." Approval is given only for entire scales (not for indicators or load cells alone). There are two types of approval:

- **EC Type Approval** for a self-contained complete scale.
- **EC "Umbrella"** Approval for a modular scale, made up of components (indicators, load cells, junction boxes, printers, etc.). Each component must have an EC Test Certificate, which must be listed on the umbrella approval.

Once an umbrella approval has been given, additional EC Test Certified components can be added to it later. The approval covers scale systems made up of various combinations of certified components. It also allows you to have one component approved while other components are still being developed.

4. Weigh Module Environmental Considerations

Because environmental factors can affect the accuracy and safety of a weigh module system, they must be considered during the design stage. If a scale will be subject to wind, seismic, or shock loading, you might need to use larger capacity weigh modules and/or add restraint devices so that the structure remains stable under extreme conditions.

Wind Loading

Scales installed outdoors or in open buildings or frameworks are subjected to wind forces which need to be considered for various reasons. Wind forces on the body of the scale cause new forces to act on the weigh modules and can lead to weigh module overload or toppling of the scale in extreme cases. They can also have a serious impact on scale performance. These points are considered further in the two sections below. Outdoor tank and silo scales are often vertical cylinders elevated on legs and supported by compression weigh modules of the general type illustrated in Figure 4-1, and is the type considered below except as noted.

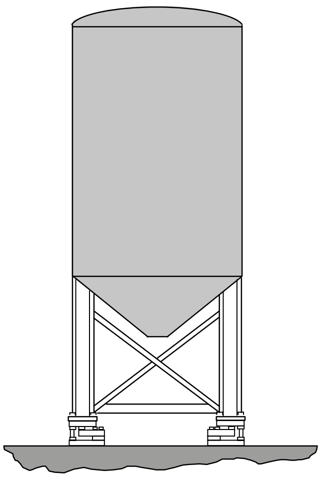


Figure 4-1: typical outdoor tank scale

Structural Stability

In the analysis of scale stability it is generally assumed that the wind can blow in any horizontal direction. Wind blowing on the side of a scale exerts a horizontal force on the windward side, this has several structural effects on the scale:

1. The weigh modules must resist the wind force by applying horizontal forces to the tank, the Max. Horizontal Force rating of the weigh modules must not be exceeded.
2. Wind forces cause weight to be transferred from the weigh module(s) on the windward side to those on the leeward side, see Chapter 10, Appendix 2, Calculating Reaction Forces, for a further discussion of this point. This can cause damage to the weigh modules if their rated capacity is exceeded and is most likely to occur when the scale is full. It may be necessary to select weigh modules of higher rated capacity. This effect can be minimized by positioning the weigh modules close to the center of gravity of the scale, as illustrated in Chapter 5, figure 5-19a.

3. In the extreme case wind forces can cause the scale to topple, especially if it is a tall slender tank or silo. Toppling is most likely to happen when the scale is empty. To resist toppling the weigh module used must have an anti-uplift feature and its Max. Uplift Force rating must not be exceeded. In extreme cases it may be necessary to add external restraints to keep high winds from tipping the tank, see "Additional Vessel Restraint Methods" in Chapter 5.

In calculating wind forces the most important factor is to determine the basic (or design) wind speed at the site, this can be found generally in isotach maps in the building codes for the region. Also of importance is the exposure at the site, for example is the scale perched on a cliff or facing a large open area of water, salt flats, etc? The scale design must be in accordance with local building codes. Furthermore, many countries require that structural design work of this type be carried out by Professional Engineers certified to practice in that region. Mettler-Toledo's position is that design for wind loading must be performed by knowledgeable and locally certified professionals in accordance with local codes for each set of circumstances; our datasheets provide the designer with the load cell and weigh module data necessary for such analysis.

Scale Performance

Wind blowing on a scale can affect both the zero and span readings, positive or negative. A steady wind can produce a steady offset in the zero and span readings; however, a gusting wind would be more typical and will cause instability in the scale's zero and span readings; at a minimum this is a nuisance making scale operation difficult, at worst it can result in serious errors in weight values. There are several means by which wind can affect a scale:

1. Wind blowing horizontally on the side of a scale can transfer load between weigh modules as described in point 2 of the previous section; this can lead to overload of some weigh modules but it can also affect the accuracy of the weight reading. Due to manufacturing tolerances, all load cells have a variation in their rated output; this is usually conveyed on datasheets by providing the rated output in mV/V followed by a ± tolerance value in the range 0.1 to 5%. If the scale is not shift adjusted (common with tank scales weighing self-leveling materials such as liquids) the weight transferred will very likely not register the same due to this variation in mV/V output of the load cells. Such errors can be minimized by choosing load cells with a small mV/V tolerance and can be eliminated by performing a shift adjustment (with a trimming J-Box) before calibration. Mettler-Toledo load cells used in weigh modules are typically adjusted so the mV/V tolerance is within ± 0.25% or better, the 0745A used in MultiMount is adjusted to ± 0.1%.

2. Wind blowing horizontally can also produce forces with a vertical component on the top and bottom surfaces of a scale. If the top and bottom surfaces were exactly symmetrical with identical flow patterns then the resulting vertical forces would be equal and opposite and would cancel. However, these conditions never exist, especially when you consider appendages such as mixers, pipes, inspection hatches and support legs. In practice these forces are difficult to quantify; the only practical approaches are to shelter the scale or place it indoors, which is always recommended when higher accuracy is required, see also the section on "Temperature Effects" below. Note that a tank situated on the leeward side of a building is not necessarily immune to wind effects; air flow over the building can produce a pressure gradient in the lee and a net vertical force on the scale.

3. If the wind blows at an angle to the horizontal then a net vertical force will be applied to the scale and this will directly affect the scale reading. This can result if the scale is situated on sloping terrain or the wind direction is modified by buildings or other obstructions. A similar problem occurs indoors if air from a fan or HVAC system is directed from above at the platter of low capacity industrial scales or laboratory balances.

4. A problem can occur with large platform scales if wind can funnel underneath causing an increase in pressure and uplift on the platform. Protect the scale by placing it in a pit with unbroken walls on all four sides.

Seismic Loading

Seismic forces caused by earthquakes are among the strongest external forces that can affect tank and silo scales. An earthquake is a sudden movement of the ground which can cause very large forces in man-made structures. Earthquakes can result from violent volcanic eruptions but more commonly and with greater severity they occur along the edges of the tectonic plates. In figure 4-2 each dot represents an earthquake of magnitude 4 or larger recorded over a 5 year period; generally speaking the dot pattern coincides with the tectonic plate boundaries. In certain areas the tectonic plates want to slide relative to one another either horizontally or vertically, and this can be prevented over long periods by friction between the plates; potential energy builds-up until friction is overcome and slippage occurs suddenly, thus producing an earthquake. Seismic shock waves radiate outwards from the focus of the earthquake producing horizontal movement of the ground and surface waves that ripple across the ground; thus earthquakes can produce both horizontal and vertical movement and corresponding forces in equipment and structures mounted on the ground.

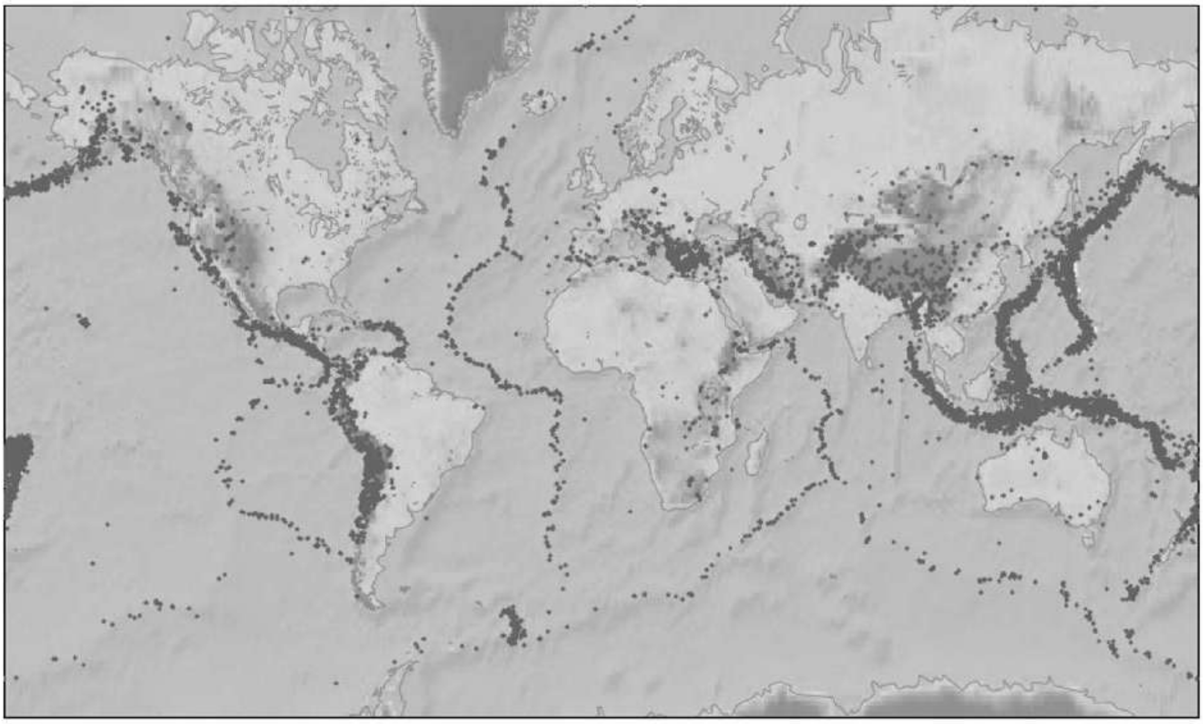


Figure 4-2, Earthquakes of magnitude 4 and greater recorded over a 5 year period Source: Iris Consortium

Seismic design of structures has evolved dramatically in the last 40 years and continues to evolve with each major earthquake as the lessons learned are incorporated into the various design codes. There are many design codes in use globally, for example, the International Building Code published by ICC is widely used in the USA, while EN1998 Eurocode 8: Design of Structures for Earthquake Resistance published by CEN is now used across Europe. In designing tanks there are additional considerations due to hydrodynamic effects of liquid sloshing in the tank; there are codes that have been written specifically for this situation and some that are relevant to elevated tanks are listed in Table 4-1.

Number	Title	Published by
EN1998-4	Eurocode 8: Design of Structures for Earthquake Resistance Part 4: Silos, Tanks & Pipelines	CEN
D100	Welded Carbon Steel Tanks for Water Storage	AWWA
D103	Factory-Coated Bolted Steel Tanks for Water Storage	AWWA
NZSEE Guideline	Recommendation for the Seismic Design of Storage Tanks	NZSEE
ACI 350.3	Seismic Design of Liquid-Containing concrete structures & Commentary	ACI

Table 4-1: Codes relevant to the Seismic Design of Elevated Tanks

Luckily most earthquakes take place in remote locations away from centers of population and industrialization, but there are many important exceptions. If the scale is located in a region where seismic design codes apply then the scale design must be in accordance with these codes. There are many factors to be considered including the severity and nature of the earthquake to be designed for, distance from known fault lines, the type and depth of soil/rock at the site, the foundation type and the position of the scale within a building or structure, the dimensions and configuration of the scale, the toxicity of the material stored and the required condition of the scale after the earthquake. Furthermore, many countries require that seismic design be carried out by Professional Engineers certified to practice in that region. Mettler-Toledo's position is that seismic design must be performed by knowledgeable and locally certified professionals in accordance with local codes for each set of circumstances; our datasheets provide the designer with the load cell and weigh module data necessary for such analysis.

Shock Loading

Shock loading of a scale may be accidental or may be inherent to its operation and should be considered at the design stage, especially that of hopper, platform, and conveyor scales. It is caused by an abrupt change in the weight on the scale, for example, when an object is dropped or lowered onto the scale. Typical examples are scrap iron weighing where the scale is loaded using an electromagnetic pickup, and floor scales used to weigh castings that are lowered onto the scale by an overhead crane. If shock forces are strong enough, you will need to install higher capacity load cells or take other measures to limit the loads applied.

To estimate the shock load caused by a dropped object, you must know the weight of the object being dropped, the vertical distance it is dropped, the empty weight of the scale structure, the number of load cells and the load cell's rated capacity and deflection. The latter is listed on the METTLER TOLEDO data sheets.

To estimate the shock load caused by a lowered object (typical of crane loading applications), you must know the weight of the object being lowered, the lowering speed, the empty weight of the scale structure, the number of load cells and the load cells' rated capacity and deflection.

Size the load cells/weigh modules in the normal way as described in Chapter 6, Compression Weigh Modules, or Chapter 7, Tension Weigh Modules. Then check to see if shock loading might damage them. Identify the load cell with the worst case loading conditions and use one of the following equations to estimate the maximum load applied to that load cell as a result of dropped or lowered loads.

Equation for Dropped load:

$$M_{MAX} = M_2 + M_1 \times \left[1 + \sqrt{1 + \frac{2 \times H \times R.C.}{(M_1 + M_2) \times \Delta}}\right] \quad (1)$$

Equation for Lowered load:

$$M_{MAX} = M_2 + M_1 \times \left[1 + \sqrt{1 + \frac{V^2 \times R.C.}{g \times (M_1 + M_2) \times \Delta}}\right] \quad (2)$$

Where:

M_{MAX} = Maximum load in lb [kg] on the worst case load cell due to dropped or lowered loads.
M_1 = Proportion of the Dropped or Lowered Load in lb [kg] carried by the worst case load cell.
M_2 = Proportion of the Scale's Dead Load in lb [kg] carried by the worst case load cell.
H = Height from which Object is Dropped in inches [mm]
R.C. = Rated Capacity (Emax) of the load cell in lb [kg]. Convert other units to lb or kg if necessary.
Δ = Load Cell Deflection at R.C. in inches [mm]. See "Using Shock/Vibration Pads" below if they are used in the application.
V = Speed at which Object is Lowered in in/s [mm/s]
g = Acceleration due to Gravity = 386 in/s^2 [= 9,810 mm/s^2]

M_{MAX} should be less than the Rated Capacity of the load cell or weigh module stated in lb [kg]. These equations provide conservative results in situations where there is significant deflection in the scale structure, for example, when a load is dropped at the center of a relatively compliant 4-load cell floor scale. Note that the equations can be used for load cells alone or for weigh modules and that in general the deflection of a weigh module is assumed to be that of the corresponding load cell. Be consistent in the use of units of measure, use lb, in, in/s and in/s^2
or kg, mm, mm/s and mm/s^2.

If additional protection against shock loading is required, one possible solution is to specify a larger capacity load cell/weigh module or you might consider one of the following:

- Change the process so that objects are placed onto the scale with less shock loading.
- Shred or crush the material to reduce lump size.
- Add mass to the scale platform.
- Use shock-absorbing materials such as Shock/Vibration pads, coil springs, railroad ties, or compacted sand to dampen impact forces.

Example, Imperial Units

A floor scale has a dead load of 400 lb and is loaded using an overhead crane with lowering speed of 3 in/s. It is to be designed so that a single item of 1,500 lb can be placed anywhere on the scale. Four 5,000 lb MultiMounts are proposed for this application. Check that the load cells will not be damaged due to shock loading.

M_1 = 1,500 lb (M1 can be lowered over a single weigh module)
M_2 = 400/4 = 100 lb (the dead load is shared equally between 4 weigh modules).
R.C. = 5,000 lb
Δ = 0.020 inches from the 0745A datasheet (the load cell used in MultiMounts).
V = 3 in/s

Using equation (2)

$$x = 100 + 1{,}500 + 1 \left[\frac{3^2 \times 5{,}000}{386 \times (1{,}500 + 100) \times 0.020}\right]$$

M_{MAX} = 4,832 lb

This is less than the weigh module's Rated Capacity and is acceptable.

Using Shock/Vibration Pads

Installing shock/vibration elastomeric pads between the weigh module top plates and the weighbridge can reduce the shock load transmitted to the load cells by increasing scale deflection under load. The effect can be included in equations (1) and (2) by adding the shock/vibration pad deflection to the load cell deflection, thus:

Δ = Load Cell Deflection at R.C. + Shock/Vibration Pad Deflection at Load Cell R.C.

To determine the Shock/Vibration pad deflection refer to the General Dimensional Layout drawing for the pads. You will find the deflection listed in in/lb and mm/kg for each pad. Multiply this number by the load cell Rated Capacity to get the Shock/Vibration Pad deflection at load cell rated capacity. See the next example which illustrates the use of Shock/Vibration pads. Note that you can download all drawings from www.mt.com, for Shock/Vibration Pad drawings go to the web page for the specific weigh module.

Example, Metric Units

A hopper scale is square in plan view and is to be built to withstand loads of 200kg dropped from 2.5m at its center. The proposal is to use 4 x 15,000 kg PinMount symmetrically placed. The dead weight of the hopper is 6,000 kg. Check that the load cells will not be damaged due to shock.

M_1 = 200/4 = 50 kg (M1 is shared equally between 4 weigh modules).
M_2 = 6,000/4 = 1,500 kg (the dead load is shared equally between 4 weigh modules).
R.C. = 15,000 kg
Δ = 0,25 mm from the SLC611 datasheet (the load cell used in Pinmount).
H = 2,500 mm

Using equation (1)

$$= 1{,}500 + 50 \times \left[1 + \sqrt{1 + \frac{2 \times 2{,}500 \times 15{,}000}{(50 + 1{,}500) + 0.25}} \right]$$

$$= 23{,}547\ \text{kg}$$

This exceeds the weigh module's Rated Capacity and is not acceptable.

As a solution look at the effect of adding Shock/Vibration pads. From the Pinmount Shock/Vibration pad drawing its deflection is 3.69×10^{-5} mm/kg of load applied and thus its deflection at the load cell's rated capacity is $3.69 \times 10^{-5} \times 15{,}000 = 0.55$ mm. As discussed above, Δ must be modified as follows:

Δ = Load Cell Deflection at R.C. + Shock/Vibration Pad Deflection at Load Cell R.C.
Δ = 0.25 + 0.55 = 0.80 mm.

With this value M_{MAX} becomes:

$$M_{MAX} = 1{,}500 + 50 \times \left[1 + \sqrt{1 + \frac{2 \times 2{,}500 \times 15{,}000}{(50 + 1{,}500) + 0.80}} \right]$$

$M_{MAX} = 13{,}847$ kg.

M_{MAX} is now less than the weigh Module Rated Capacity and is acceptable.

Vibration

If a scale vibrates constantly, it might not come to rest long enough to capture an accurate weight reading. METTLER TOLEDO indicators have built-in filtering systems that can eliminate most of the effects of vibration. When installing a weigh module system, you should take steps to reduce any external or internal vibration that the indicator cannot eliminate.

External Vibration: A scale can be affected by vibration from its foundation or from the surrounding environment. We recommend finding the source of the vibration and correcting it to eliminate its effect on the scale. Cutting the floor slab or separating the scale support frame from surrounding structures can also prevent external vibration from affecting a scale's stability.

Internal Vibration: Vibrations produced inside a tank are normally caused by sloshing liquid or agitation. In large tanks, sloshing can produce low-frequency vibrations that are difficult to eliminate at the scale indicator. You can reduce sloshing by installing baffles in a tank. If an agitator and its drive motor are permanently attached to a scale, you might need to incorporate isolation pads (such as Shock/Vibration pads, available from METTLER TOLEDO) in the mounting of the weigh modules to minimize the internal vibration. These problems can be avoided if the agitator can be stopped while weight readings are taken.

It is difficult to analyze the random effects of vibration caused by wind. If high accuracy is required, we recommend indoor installations or shielding the scale from wind. Any time a tank is located outdoors, it should be designed to minimize vertical forces resulting from wind.

Temperature Effects

A scale and its weighing components can change temperature for many reasons:

- Changes in ambient air temp:
  - Daily, those that occur in a 24 hour period.
  - Seasonal, those that occur over the course of a year.
- Heat conduction from:
  - Heating/cooling jackets on tanks
  - Weighing of heated liquids
  - Exothermic chemical reactions in reactors
- Radiant heating effects from:
  - The sun
  - The tank scale contents and/or its heating jacket
  - Adjacent process equipment, e.g., furnaces

Temperature changes can affect a scale in three important ways:

1. Temperature effect on Min. Dead Load Output of the weighing components.
2. Temperature effect on Sensitivity of the weighing components.
3. Thermal expansion/contraction of the scale structure.

Temperature effect on Min. Dead Load Output

Also referred to as Temperature Effect on Zero, this is a situation where the zero reading of load cells and terminal (and hence scale) changes as a function of temperature. The effect is quantified in the respective datasheets. For example, the Temp. Effect on Min. Dead Load Output for the 0745A load cell is given as ≤ 0.0007% R.C./°F [0.0013% R.C./°C]; this means that the load cell's zero reading can change by up to 0.0007% of rated capacity per ° F [0.0013% of rated capacity per °C] change in temperature. The change can be positive or negative.

Example:
If a 500 lb [220 kg] 0745A load cell is installed in a room where the temperature can vary by 18°F [10°C] in 24 hours, what is the maximum change in the load cell's zero output in lb [kg]?

From the 0745A datasheet we know that its Temp. Effect on Min. Dead Load Output specification is 0.0007% R.C./°F [0.0013% R.C./°C].

$$\text{Max. change in zero} = \frac{0.0007 \times 500 \times 18}{100} \quad \left[\frac{0.0013 \times 220 \times 10kg}{100}\right] = 0.063 \qquad [0.029\ \text{kg}]$$

The change can be positive or negative.

If a scale is sitting idle unloaded then Temp. Effect on Min. Dead Load Output can cause the display to read other than zero and if a weighment commences then the weight value will be in error by that amount. Such errors can be avoided by zeroing the scale before the weighment commences or by using Automatic Zero Maintenance (AZM) to automatically maintain the zero point.

Temp. Effect on Min. Dead Load Output can cause the zero point to move during a weighment thus causing a corresponding error in the weight reading. In transaction weighing the weighment cycle is typically short, a minute or so. This means that temperature changes and hence errors due to Temp. Effect on Min. Dead Load Output are insignificant.

Errors due to Temp. Effect on Min. Dead Load Output can be significant when:
1. Scale loading times are long (weigh-in scales).
2. Scale unloading times are long (weigh-out scales).
3. When scales remain loaded for prolonged periods, for example, storage silos.

This is an absolute error dependent on load cell capacity and is independent of the load weighed. Problems are most acute in the above situations when dead load is high (forcing you to use an otherwise oversized load cell) and you are weighing near zero load.

These errors can be minimized by:
1. Using quality temperature compensated weighing components. Those with the lowest Temp. Effect on Min. Dead Load Output specification are best.
   a. If comparing load cells based on metrology approvals, select those with the smallest Vmin value. Note: HB44 class III L Vmins are not directly comparable, these must be multiplied by 3 before making a comparison to class III Vmins.
2. As can be seen in the example above, Temp. Effect on Min. Dead Load Output depends on the Rated Capacity of the load cell and will be the same regardless of the load being weighed. For this reason use the smallest capacity load cell possible for the application, consistent with the other requirements of robustness, etc., see Chapter 6, Compression Weigh Modules, or Chapter 7, Tension Weigh Modules for more information on sizing load cells.
3. Minimizing loading (weigh-in scale) or unloading (weigh-out scale) times.
4. Minimizing air temperature fluctuations; install the scale indoors or, better still, install in a temperature controlled room.
5. Minimizing heat conduction to the weighing components.
   a. Do not mount the terminal and junction box to the side of a heated tank.
   b. Long legs (or long suspension rods in the case of tension installations) reduce conduction of heat from the tank to the weigh modules. In addition, the installation of thermal isolation pads* between a tank's legs and compression weigh modules can provide further isolation.
6. Minimizing radiant heating effects by installing heat shields between the source and the weighing components. Where possible, avoid positioning scales beside radiant heat sources such as furnaces.

* Mettler Toledo provides two forms of thermal isolation pads, acetal and polyetherimide (PEI). These function in the same way but PEI has a lower thermal conductivity and withstands higher operating temperatures; refer to their dimensional drawings on mt.com/ for further information.

Temperature effect on Sensitivity

Also referred to as Temperature Effect on Span, this is a situation where the sensitivity (or span calibration) of load cells and terminal (and hence scale) changes as a function of temperature. The effect is quantified in the respective datasheets. For example, the Temp. Effect on Sensitivity for the 0745A load cell is given as ≤ 0.0005% A.L./°F [0.0009% A.L./°C]; this means that the load cell's weight reading can change by up to 0.0005% of applied load (A.L.) per °F [0.0009% of applied load per °C] change in temperature. The change can be positive or negative.

Example:

If a single 2.5t SLS410 load cell is used to weigh 4,000 lb [2,000 kg] of applied load repeatedly and is installed in a room where the temperature can vary by 18°F [10°C] in 24 hours, what is the maximum error due to temperature effect on Sensitivity in lb [kg]?

From the SLS410 datasheet we know that its Temp. Effect on Sensitivity specification is 0.0008% A.L./°F [0.0014% A.L./°C]

$$\text{Max. error} = \frac{0.0008 \times 4{,}000 \times 18 Ib}{100} \left[\frac{0.0014 \times 2{,}000 \times 10 kg}{100}\right] = 0.58 \text{ lb } [0.28 \text{ kg}]$$

The change can be positive or negative.

These errors can be minimized by:

1. Using quality temperature compensated weighing components. Those with the lowest Temperature effect on Sensitivity specification are best. If comparing components based on metrology approvals, select those with the higher accuracy class and then the larger Maximum Number of Verification Intervals (nmax) within the class. For example, HB44 class III is superior to class III L, and class III 5,000 e is superior to class III 3,000 e. Likewise OIML R76-1 class III is superior to class IIII, and class III 6,000 e is superior to class III 3,000 e. Likewise for OIML R60 load cells, class C is superior to class D and C6 is superior to C3.
2. See also recommendations 4 to 6 under **Temperature effect on Min. Dead Load Output** above which are applicable here also.

Thermal expansion/contraction of the Scale Structure

Thermal expansion/contraction can cause:

1. Mechanical binding of the scale
2. Extraneous horizontal forces and moments to be applied to the load cells
3. Pipes to exert axial forces on a tank scale

When a scale expands or contracts it can bind against adjacent structures or within the weigh module. For example, an in-pit floor scale can expand against the pit wall if there is not sufficient clearance to begin with. Also, if a scale on weigh modules with live-to-dead checking expands to the point where the Top Plate Travel specification is exceeded, then binding will take place within the weigh modules. In both cases the live scale binds against a dead structure; as load is applied the scale is restrained from moving freely in the vertical direction and grossly inaccurate weights can result.

If a scale is rigidly connected to load cells then any expansion or contraction of the scale will result in undesirable side forces or moments being applied to the load cells. This can result if a scale structure is bolted rigidly to load cells or with poorly designed weigh modules that lack a suspension to allow lateral movement. See Applying Force to Load Cells in Chapter 5, for more information.

Temperature changes can cause rigid pipes to expand and contract thus exerting axial forces on a tank scale. These forces can be particularly destructive to accuracy if the pipes connect vertically to the tank, see also Piping Installation in Chapter 5, for more information.

The following equation can be used to calculate the change in the length of an object as the temperature changes:

$\Delta L = \alpha \times L \times \Delta T$

Where:

ΔL = Change in Length, in [mm]

α = Coefficient of Linear Expansion, in/in °F [mm/mm °C], see Table 4-2 below.

L = Original Length, in [mm]

ΔT = Change in Temperature, °F [°C]

	Coefficient of Linear Expansion (α)	
Material	in/in °F	mm/mm °C
Aluminum alloys	$12.8 \times 10^{-6} – 13.2 \times 10^{-6}$	$23.0 \times 10^{-6} – 23.8 \times 10^{-6}$
304 Stainless	9.6×10^{-6}	17.3×10^{-6}
316 Stainless	8.9×10^{-6}	16.0×10^{-6}
17-4PH Stainless	6.0×10^{-6}	10.8×10^{-6}
Mild Steel	6.5×10^{-6}	11.7×10^{-6}
4340 Alloy Steel	6.3×10^{-6}	11.3×10^{-6}

Table 4-2, Coefficient of Linear Expansion for some common materials

Example 1

A 304 stainless steel pipe is 60 in [1’525 mm] long and its temperature changes from 70°F [21°C] to 205°F [96°C], what is the resulting change in length of the pipe?

From Table 4-2, $\alpha = 9{,}6 \times 10^{-6}$ in/in °F [17.3×10^{-6} mm/mm °C]

L = 60 in [1,525 mm]

$\Delta T = 205 – 70 = 135$°F [$96 – 21 = 75$°C]

$\Delta L = \alpha \times L \times \Delta T$

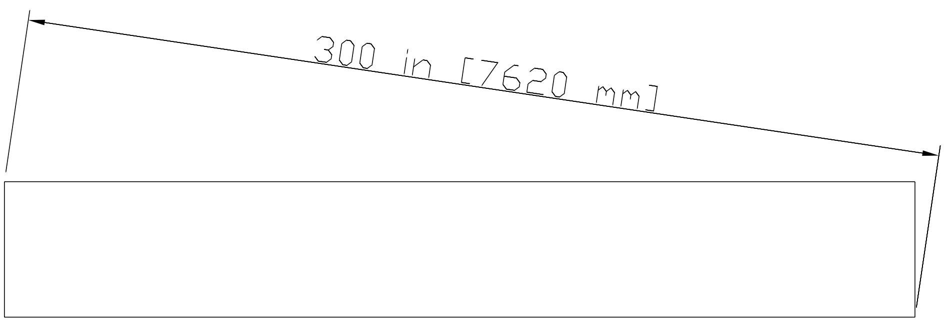
$\Delta L = 9.6 \times 10^{-6} \times 60 \times 135$ [$17.3 \times 10^{-6} \times 1{,}525 \times 75$]

$\Delta L = 0.078$ in [2.0 mm]

The pipe increases in length by 0.078 in [2.0 mm].

Example 2

A conveyor scale made from mild steel measures 300 in [7,620 mm] across a diagonal (the maximum distance between 2 weigh modules) as illustrated. The scale is installed outdoors with an expected seasonal temperature range of 0°F to 120°F [-18°C to 49°C], what is the resulting expansion and contraction across the diagonal using 70°F [21°C] as the reference point?



From Table 4-2, $\alpha = 6.5 \times 10^{-6}$ in/in °F [11.7×10^{-6} mm/mm °C]

L = 300 in [7,620 mm]

Considering expansion only:

ΔT = 120°F - 70°F = 50°F [49°C - 21°C = 28°C]

$\Delta L = \alpha \times L \times \Delta T$

$\Delta L = 6.5 \times 10^{-6} \times 300 \times 50$ [$11.7 \times 10^{-6} \times 7{,}620 \times 28$]

ΔL = 0.10 in [2.5 mm]

The scale will expand on the diagonal by 0.10 in [2.5 mm] when the temperature increases from 70°F to 120°F [21°C to 49°C].

Considering contraction only:

ΔT = 70°F - 0°F = 70°F [21°C - (-18°C) = 39°C]

$\Delta L = \alpha \times L \times \Delta T$

$\Delta L = 6.5 \times 10^{-6} \times 300 \times 70$ [$11.7 \times 10^{-6} \times 7{,}620 \times 39$]

ΔL = 0.14 in [3.5 mm]

The scale will contract on the diagonal by 0.14 in [3.5 mm] when the temperature decreases from 70°F to 0°F [21°C to -18°C].

Example 3.

Is MultiMount or PinMount the more suitable Weigh Module for the scale in Example 2 above, conisdering Max. Top Plate Travel only?

MultiMount with Stabilizer:
The stabilizers effectively create one fixed corner, so that one weigh module must accommodate all expansion/contraction on the diagonal. MultiMount Size 1, 11 - 660 lb [5 - 300 kg], has a Max. Top Plate Travel spec of ± 0.1 in [2.5 mm]. This would exactly accommodate the expansion case above but not the contraction and should not be used. MultiMount Size 2, 250 - 5000 lb [110 - 2200 kg], has a Max. Top Plate Travel spec of ± 0.12 [3 mm], which is below the required contraction, and should not be used. MultiMount Size 3, 10000 lb [4400 kg], has a Max. Top Plate Travel spec of ± 0.14 [3.5 mm], which is exactly the required contraction, so it can be used.

MultiMount without Stabilizer:
Without stabilizers, the MultiMounts at each end of the diagonal can accommodate ± 0.1 in [2.5 mm], ± 0.12 in [3 mm] and ± 0.14 in [3.5 mm] (Size 1, 2, and 3, respectively) each of expansion/contraction. So the total expansion/contraction possible on the diagonal is ± 0.2 in [5 mm], ± 0.24 in [6 mm], ± 0.28 in [7 mm] (Size 1, 2, and 3, respectively); much more than required in Example 2 and is suitable.

PinMount with Stabilizer:
The stabilizers effectively create one fixed corner, so that one weigh module must accommodate all expansion/contraction. PinMount up to and including 220 klb [100 ton] has a Max. Top Plate Travel spec of ± 0.2 in [5 mm] and is suitable for the scale in Example 2. (PinMount 440 and 660 klb [200 and 300 ton] has no stabilizer option.)

PinMount without Stabilizer:
Without stabilizers, the PinMounts at each end of the diagonal can accommodate ± 0.2 in [5 mm] (± 0.24 in [6 mm] for 440 and 660 klb capacities) each of expansion/contraction. So the total expansion/contraction on the diagonal is ± 0.4 in [10 mm] (± 0.48 in [12 mm]); much more than required in Example 2 and is suitable.

Moisture and Corrosion

Moisture or corrosive material on a weigh module can affect the life of the load cells. Debris, such as leaves and dirt, accumulated in and around weigh modules can also cause problems. There are several steps you can take to minimize the potential for moisture and corrosion problems:

- Provide adequate drainage away from the weigh modules.
- Keep weigh modules clear of snow that will melt and introduce moisture into the system.
- Do not use tanks with flat tops that catch and retain water, snow, leaves, or other debris that will add uncompensated weight to the system.
- Hose down the tanks regularly to clean accumulated debris.
- Keep cables clean and in good condition. Broken cables or worn cable sheathing can allow water to enter and cause corrosion.
- Protect cables by placing them in conduit or FEP/PTFE wrap.
- Locate tanks (and weigh modules) away from corrosive materials and chemicals. The combined effects of temperature, water, and air can corrode nearby weigh modules. If tanks are near corrosive substances, provide protective coatings and shieldings. Positive airflow in the area can also help prevent corrosion damage.
- Store tools, supplies, and trash away from the tank and weighing system.

NEMA/IP classifications for electrical equipment enclosures are covered in Chapter 10, Appendix 4, NEMA/IP Enclosure Types. A chemical resistance chart is provided in Chapter 10, Appendix 6, Chemical Resistance Chart.

Lightning and Surge Protection

Lightning protection devices should be installed to protect a scale from being damaged by lightning. Use devices that are designed to keep the current produced by lightning from reaching ground through the load cell. Instead, the devices should provide a low-resistance alternative path to ground near each weigh module (see Figure 4-3).

- Verify the integrity of any existing grounding systems.
- Use a single-point grounding system.

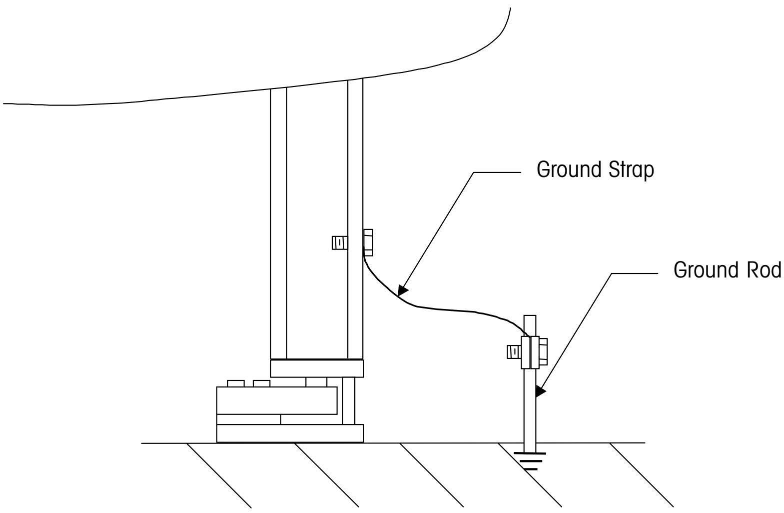


Figure 4-3: Grounding System for a Weigh Module

Surges are brief changes in voltage or current. They can be caused by lightning or by equipment with large motor loads (HVAC systems, variable-speed motors, etc.). Minor power surges can be eliminated by using an Uninterruptable Power Supply (UPS) or Power Conditioner. You should provide surge protection to prevent damage to a weigh module system.

5. Tank and Vessel Design

Applying Force to Load Cells

Load cells that use strain gauges are sensitive enough to detect very small changes in weight. The trick is to make sure that they react only to the weight you want to measure, not to other forces. To get accurate weight readings, you must carefully control how and where weight is applied to a load cell. Ideally, a load cell should be installed so that the load is applied vertically throughout the entire weight range (see Figure 5-1).

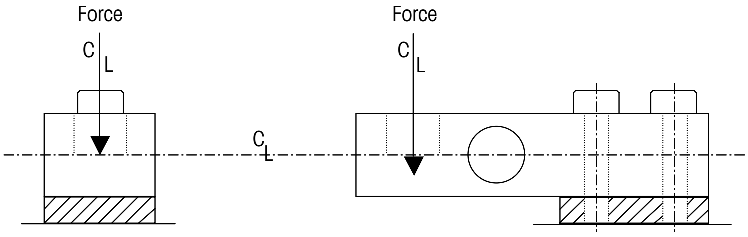


Figure 5-1: Ideal Loading (Entire Force Applied Vertically)

To attain that ideal, the weigh vessel and load cell support would need to be level, parallel, and infinitely rigid. When a tank scale and its structural supports are designed and installed carefully, it is possible for the scale to approach an ideal loading application. When a scale is not installed properly, there are several types of forces that can affect its accuracy. The following sections describe loading problems commonly encountered in tank scale applications.

Angular Loading

Angular loading occurs when a force that is not perfectly vertical is applied to a load cell. This diagonal force can be defined as the sum of its vertical component and its horizontal component. In a well-designed weigh module application, the load cell will sense the weight (vertical force) but will not sense the side load (horizontal force).

Figure 5-2a and Figure 5-2b show a weigh module application with the load cell anchored to a foundation. In Figure 5-2a, the force exerted by the tank's weight is perfectly vertical. In Figure 5-2b, the force is applied at an angle. The vertical component (F) of this angular force is normal to and sensed by the load cell; it is equal to the force applied in Figure 5-2a. The horizontal component (side load) = F × Tangent θ.

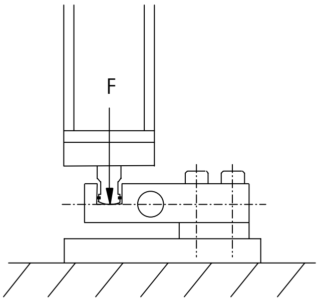


Figure 5-2a: Vertical Force

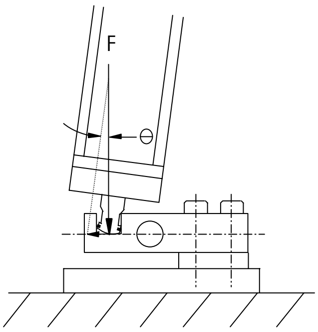


Figure 5-2b: Angular Force

Figure 5-3a and Figure 5-3b show how angular loading would affect a load cell anchored to the tank that is being weighed. Figure 5-3a shows an ideal installation with a perfectly vertical force. In Figure 5-3b, the force (F_N) that is normal to and sensed by the load cell would be less than the vertical force (F) applied to the load cell in the ideal installation. In this case, $F_N = F \times \text{Cosine } \theta$.

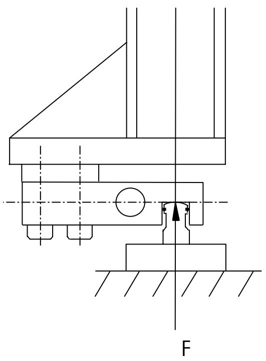


Figure 5-3a: Vertical Force

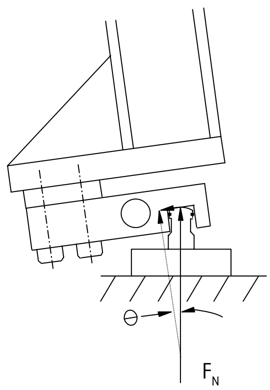


Figure 5-3b: Angular Force

Eccentric Loading

Eccentric loading occurs when a vertical force is applied to a load cell at a point other than its center line (see Figure 5-4). This problem can be caused by thermal expansion and contraction or by poorly designed mounting hardware. You can avoid eccentric loading problems by using a weigh module system that will compensate for expansion and contraction.

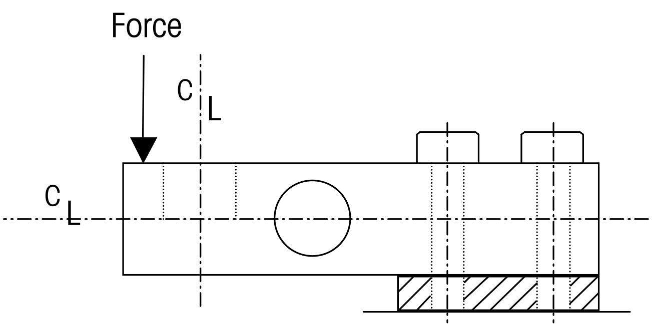


Figure 5-4: Eccentric Loading

Side and End Loading

Side and end loading occur when horizontal forces are applied to the side or end of a load cell (see Figure 5-5). They can be caused by thermal expansion and contraction, by misalignment, or by vessel movement due to dynamic loading. Side and end forces can affect the linearity and hysteresis of the scale. For static loading applications, use a weigh module system that compensates for thermal movement. For dynamic loading applications, use a weigh module system with a self-aligning load pin suspension.

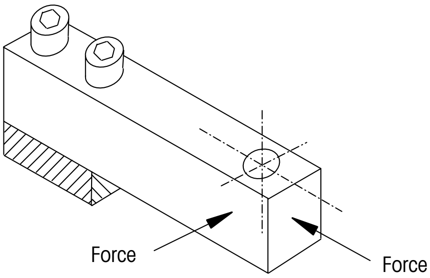


Figure 5-5: Side and End Forces Applied to a Load Cell

Torsional Loading

Torsional loading occurs when a side force twists a load cell (see Figure 5-6). It can be caused by structural deflection, system dynamics, thermal movement, or mounting hardware misalignment. Torsional loading will reduce a system's accuracy and repeatability. To avoid this problem, always follow proper structural support and installation guidelines, and use weigh modules that compensate for tank movement.

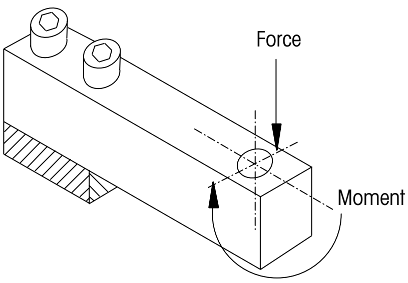


Figure 5-6: Torsional Loading Applied to a Load Cell

Applying Force to Weigh Modules

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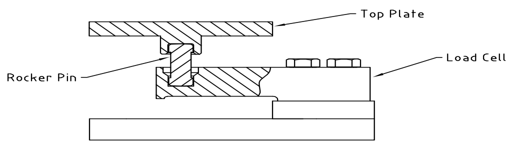
Weigh modules are designed to introduce the load correctly to the load cell while avoiding the application of undesirable forces as discussed in the previous section. Figure 5-7 is a simplified cross-section through the top plate of MultiMount, a typical compression weigh module.



* replace image:
Picture 2 (1).pdf

Figure 5-7: Simplified cross-section through MultiMount top plate

It shows the top plate sitting on the rocker pin which is the means of introducing the load to the load cell. The upper surface of the rocker pin has a spherical radius which means that the top plate is simply supported at a single point, ideally the center point of the top plate. In addition, weigh modules must have a mechanism to allow the top plate to move horizontally due to thermal expansion and contraction, in which case the rocker pin in 5-7 tilts causing the point of support to the top plate to move laterally away from the center point. There are three important consequences of the foregoing:

1. There is no means of applying a moment to the top plate to keep it from rotating out of the horizontal plane ; this is by design to protect the load cell from the extraneous forces discussed in the previous section.
2. There is a natural tendency for the top plate to rotate out of the horizontal plane. Even if the top plate is loaded centrally from above, the point of support below can be slightly eccentric due to thermal expansion/contraction, thus producing a couple tending to rotate it. This situation is exacerbated by unavoidable manufacturing and installation tolerances.
3. The load introduction components have no ability to resist uplift forces.

These points are true of most weigh modules and have several implications for the designer of compression scales:

- A single compression weigh module cannot support a weighing platform, tank, etc. A minimum of three is required. In plan view the weigh modules cannot be in a straight line, three must be arranged in a triangular pattern, four in a square or rectangular pattern, etc.
- The vertical weight force acting at the center of gravity of the scale should always be within the confines of the horizontal plane defined by the points of support to the weigh modules top plates; it should never be outside. In other words, under normal weighing conditions there must be some downward force on all weigh modules; even momentary lifting and separation of the load introduction components will greatly affect the repeatability of the scale. The rated capacity of any weigh module cannot be exceeded as the load cell may be damaged; ideally the center of gravity would be centered so that all weigh modules are loaded equally.
- See figure 5-8, weigh modules must be sandwiched between a rigid foundation below and a rigid scale structure above to ensure that the base and top plates remain * horizontal. The foundation can be concrete or structural steelwork. The scale structure can be a steel platform, tank, hopper, etc. that provides rigidity to the weigh module top plates. If a tank has long legs it is important that they be strong and cross-braced, see Figures 5-15a and 5-15b below.

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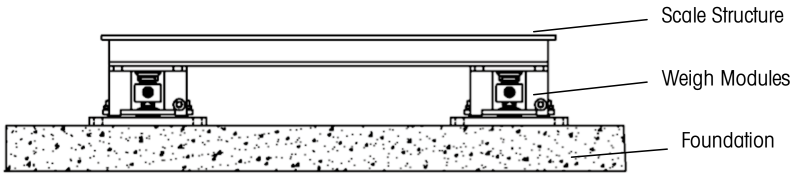

Figure 5-8: Typical Scale Configuration (2 of 4 weigh modules visible)

- The base plates cannot sit directly on casters or wheels as shown in Figure 5-9. Portable scales can be constructed but there must be a rigid frame between the wheels/casters and the weigh module base plates.

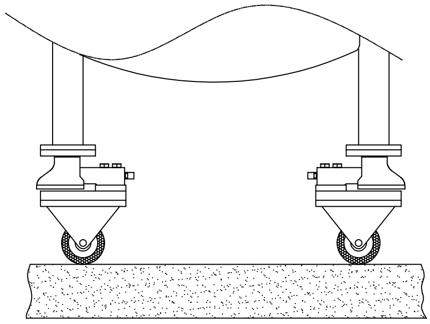

Figure 5-9: Incorrect design for portable tank scale

- The connection of the weigh module top plate to the scale structure must be rigid, for example, it cannot be through a slender stem as shown in Figure 5-10. This is a consequence of point 2. above, any eccentricity of the underside support to the top plate will produce a couple tending to bend the stem. See also Support Deflection below for further information.

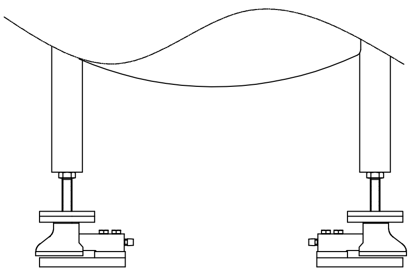

Figure 5-10: Incorrect attachment of leg to weigh module top plate.

- Weigh modules based on a rocker pin (or rocker pin load cell) must have the anti-lift function provided by some other means, for example, an anti-lift screw incorporated within the weigh module.

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Piping Design

The biggest challenge in designing tank and reactor scales is how to limit the potentially serious impact of piping on scale performance.

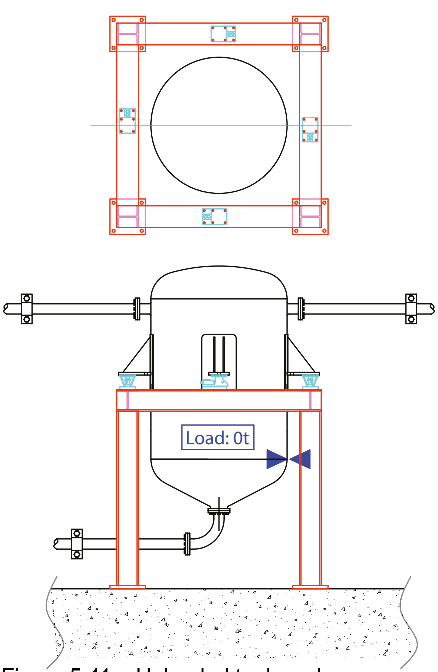

Figure 5-11a: Unloaded tank scale

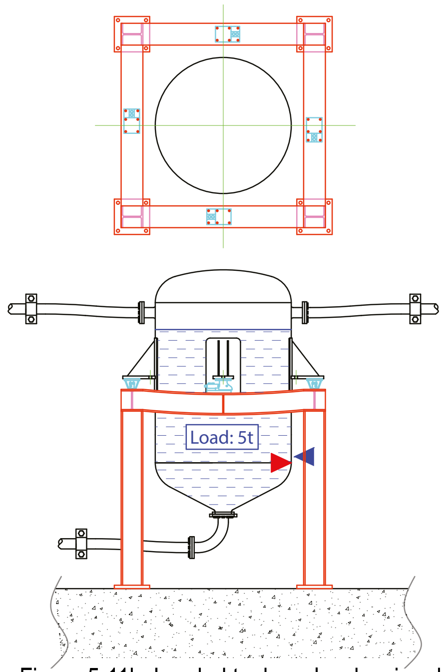

Figure 5-11b: Loaded tank scale, showing deflected structure and piping

Figure 5-11a shows a typical unloaded tank scale mounted on a steel structure, and Figure 5-11b shows the same scale loaded with 5 t, as an example. Under load a scale will deflect downward for a combination of reasons:

1. The inherent deflection of the load cell which is typically small in the range 0.010 to 0.040 inches [0.25 to 1 mm] at Rated Capacity.
2. The weigh module hardware is typically rigid but there are exceptions such as SWB220 where the elastomeric element causes additional deflection, see the datasheet for details.
3. The deflection of the support structure. This is often the major source when a scale is mounted on a steel structure or mezzanine floor.
4. The localized deflection of the support brackets on the side of the tank, where applicable.
5. The deflection of Shock/Vibration pads, where used.

Ideally pipes are fitted horizontally to a tank while it's unloaded, so the vertical pipe forces are zero initially. As the scale is filled, it deflects downwards and the pipes impart an increasing force in the upward direction, thus shunting load that cannot be measured by the load cells. The load shunted can be large, depending on the amount of deflection, pipe stiffness and the number and design of the pipes. Depending on scale capacity, this can have a very detrimental effect on performance. The approach to designing such a scale is as follows:

a. Determine the acceptable vertical pipe force that can be tolerated considering the scale capacity and accuracy requirement, see the next section.

b. Design the scale foundation and piping so that, the maximum vertical pipe force is not exceeded at scale capacity. See Structural Support Guidelines and below in this section.

c. Calibrate the scale using a method that exercises the scale by application of a load or force, for example, test weight, material substitution or RapidCal™. Do not use electronic simulation methods or CalFree/CalFree Plus as these methods are theoretical and cannot detect and compensate the effect of the pipes on scale sensitivity. See the section Weigh Module System Calibration.

In summary, the approach is to reduce pipe forces to an acceptable and repeatable level during the design phase, and then to calibrate out the remaining effect during installation. Note that this discussion refers to pipes for brevity, but the same concepts apply to any attachments to scales, including cables, ladders and catwalks.

Determining Acceptable Pipe Force

Figure 5-12a shows a tank mounted on weigh modules and supported by an I-beam. A pipe is connected to the tank and rigidly clamped to another structure at a distance (L) from the tank. When the tank is empty, the pipe remains in a horizontal position and exerts no force on the tank. When the tank is full (see Figure 5-12b), it moves downward because of the deflection of the load cell and the I-beam. This pulls the pipe downward the same distance that the tank deflects (Δh). The pipe acts like a guided cantilever beam and exerts an upward force on the tank, affecting weight measurements.
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Any piping connections to a tank will apply some restraining force as the tank deflects under load, how do you

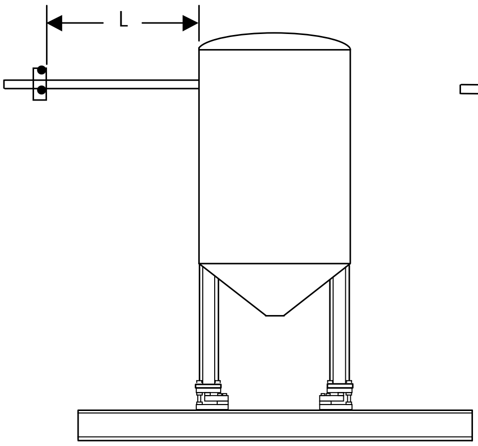


Figure 5-12a: Empty Tank

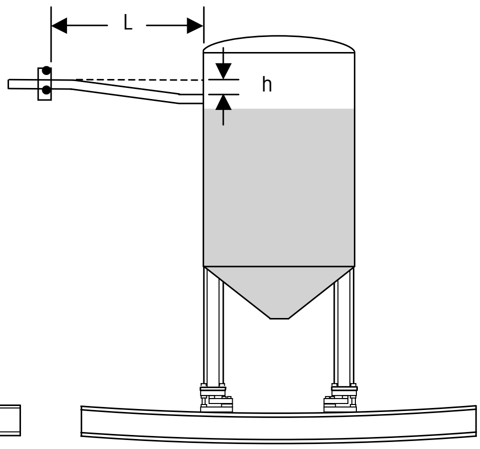


Figure 5-12b: Full Tank

determine what is acceptable? This is a function of the Scale Capacity and the System Accuracy required.
The acceptable vertical force F that may be exerted on a tank scale by all attached piping (any combination of rigid and flexible pipes and expansion joints) is given by the following empirical relationship:

In Imperial units:

$$F \leq 0.1 \times \text{System Accuracy} \times \text{Scale Capacity} \qquad (1)$$

where:
F is in lb
System Accuracy is the required system accuracy stated as a % of Scale Capacity.
Scale Capacity is the maximum live load in lb that the scale is expected to weigh.

In Metric SI units:

$$F \leq 0.1 \times \text{System Accuracy} \times \text{Scale Capacity} \times g \qquad (2)$$

where:

F is in N

System Accuracy is the required system accuracy stated as a % of Scale Capacity.
Scale Capacity is the maximum live load in kg that the scale will be expected to weigh.
g is the acceleration due to gravity = 9.81 m/s^2.

Example 1, Imperial units
If the system accuracy is to be 0.25% on a tank scale with Scale Capacity of 2,000 lb, the attached piping in total can exert a vertical force F as follows:

$$F \leq 0.1 \times 0.25 \times 2{,}000$$
$$F \leq 50 \text{ lb}$$

Example 2, Metric SI units
If the system accuracy is to be 0.05% on a tank scale with Scale Capacity of 10,000 kg, the attached piping in total can exert a vertical force F as follows:

$$F \leq 0.1 \times 0.05 \times 10{,}000 \times 9.81$$
$$F \leq 490 \text{ N}$$

Tips

Rigid Pipes

You can use the following equation to calculate the vertical force exerted by a single horizontal pipe attached to a tank:

$$F_P = \frac{0.59 \times (D^4 - d^4) \times \Delta h \times E}{L^3} \qquad (3)$$

where (Imperial units):
F_P = Vertical force exerted by a single horizontal pipe in lb
D = Outside diameter of pipe in inches
d = Inside diameter of pipe in inches
Δh = Tank deflection in inches when Scale Capacity is added to the tank. See "Calculating Δh" below.
E = Young's modulus in lb/in^2 which varies by material of construction, here are the values for three common materials:

- Carbon Steel = 29,000,000 lb/in^2
- Stainless Steel = 28,000,000 lb/in^2
- Aluminum = 10,000,000 lb/in^2

Length of pipe from the vessel to the first support point in inches.

where(metric SI units):
F_P = Vertical force exerted by a single horizontal pipe in N.
D = Outside diameter of pipe in mm.
d = Inside diameter of pipe in mm.
Δh = Tank deflection in mm when Scale Capacity is added to the tank. See "Calculating Δh" below.
E = Young's modulus in N/mm^2 and varies by material, here are the values for three common materials:

- Carbon Steel = 200,000 N/mm^2
- Stainless Steel = 190,000 N/mm^2
- Aluminum = 68,950 N/mm^2

L = Length of pipe from the vessel to the first support point in mm.

This equation assumes a pipe of circular cross-section rigidly fixed at the bracket end and free but guided at the tank end; it is generally conservative. Use it to calculate the force exerted by each rigidly attached pipe. Then sum the forces exerted by all pipes (any combination of rigid and flexible pipes and expansion joints) to determine the total resultant force (F) exerted on the tank. Make sure this is ≤ the limiting value of F as calculated in Equation (1) or (2) above.

Flexible Piping/Expansion Joints

Using flexible piping or expansion joints makes it much easier to design a piping system that will meet the requirements of Equation (1) or (2) above. Remember that it is lateral movement of the flexible pipe or expansion joint that is of importance, not the axial movement; this is because we recommend that they be installed horizontally. In order to evaluate the effect on a tank scale the lateral spring rate (in lb/in or N/mm) of the flexible pipe or expansion joint must be known.

You can use the following equation to calculate the vertical force exerted by a single horizontal flexible pipe or expansion joint attached to a tank:

$$F_c = \text{Lateral Spring Rate} \times \Delta h \qquad (4)$$

where (Imperial units):
F_c = Vertical force exerted by a single horizontal flexible pipe or expansion joint in lb
Lateral Spring Rate is the lateral spring rate in lb/in specified for the flexible pipe or expansion joint.
Δh = Tank deflection in inches when Scale Capacity is added to the tank. See "Calculating Δh" below.

where (Metric SI units):
F_c = Vertical force exerted by a single horizontal flexible pipe or expansion joint in N
Lateral Spring Rate is the lateral spring rate in N/mm specified for the flexible pipe or expansion joint.
Δh = Tank deflection in mm when Scale Capacity is added to the tank. See "Calculating Δh" below.

Use this equation to calculate the force exerted by each attached flexible pipe or expansion joint. Then sum the forces exerted by all pipes (any combination of rigid and flexible pipes and expansion joints) to determine the total resultant force (F) exerted on the tank. Make sure this is ≤ the limiting value of F as calculated in Equation (1) or (2) above.

Where the piping is subject to pressure fluctuations, it is best to avoid flexible piping and expansion joints that allow axial movement as these will act like a piston pushing/pulling the tank. If positioned horizontally they will transfer weight between the weigh modules and are best avoided. If positioned vertically the forces exerted on the tank directly impact the weight reading and must be avoided, see figure 5-14 and accompanying text below for more details.

Calculating Δh

Δh is the total deflection in inches [mm] of the tank when Scale Capacity is added. It may be calculated as follows:

$$\Delta h = \frac{\text{Load cell Deflection @ R.C.} \times \text{Scale Capacity}}{\text{Load Cell Rated Capacity (R.C.)} \times N} + \text{Structural Deflection} \qquad (5)$$

Where (Imperial units):
Δh is in inches.

Load Cell Deflection @ R.C. in inches is available in product datasheets. Note that a weigh module's deflection is generally assumed to be that of the load cell.

Scale Capacity is the maximum live load in lb that the scale will be expected to weigh.

Load Cell Rated Capacity (R.C.) is available from the weigh module's datasheet. Convert to lb if necessary.

N is the number of load cells supporting the scale.

Structural Deflection is the deflection in inches of the tank resulting from deflection of the support structure under the tank.

Where (metric SI units):
Δh is in mm.

Load Cell Deflection @ R.C. in mm is available in product datasheets. Note that a weigh module's deflection is generally assumed to be that of the load cell.

Scale Capacity is the maximum live load in kg that the scale will be expected to weigh.

Load Cell Rated Capacity (R.C.) is available from the weigh module's datasheet. Convert to kg if necessary.

N is the number of load cells supporting the scale.

Structural Deflection is the deflection in mm of the tank resulting from deflection of the support structure under the tank.

This calculation assumes that the first bracket on the piping is fixed and not moving with the tank's support structure.

Sample Calculations

Example 3, Imperial Units
Suppose a customer requires a tank scale to have a System Accuracy of 0.1% and a Scale Capacity of 25,000lb. One rigid pipe will be connected to the tank horizontally. Check if the pipe selected is acceptable. Other characteristics are as follows:
D = 4.00 inches (Outside diameter of pipe)
d = 3.75 inches (Inside diameter of pipe)
Δh = 0.09 inches (Total deflection of the tank)
Carbon steel pipe, therefore $E = 29 \times 10^6$ lb/in^2 (Young's modulus)
L = 60 inches (Length of pipe from the vessel to the first support point)

Use Equation (1) to determine F, the maximum total pipe force allowable when Scale Capacity is applied to the scale:

$$F \leq 0.1 \times 0.1 \times 25{,}000 \text{ lb}$$
$$F \leq 250 \text{ lb}$$

Hence, F cannot be greater than 250 lb.
Use Equation (3) to calculate the actual force exerted by the pipe:

$$F_P = \frac{0.59 \times (256.00 - 197.75) \times 0.09 \times 29{,}000{,}000}{216{,}000} = 415 \text{ lb}$$

Since a pipe force of 415 lb is greater than 250 lb, it would not satisfy the requirement for a system with 0.1% System Accuracy. One solution is to increase the length of the pipe from 60 inches to 80 inches. When you recalculate the pipe force for a length of 80 inches, you get F_P = 175 lb, which is well below the maximum of 250 lb and is acceptable.

Example 4, Metric SI Units

Suppose a customer requires a tank scale to have a System Accuracy of 0.05% and a Scale Capacity of 20,000 kg. One rigid pipe will be connected to the tank horizontally. Check if the pipe selected is acceptable. Other characteristics are as follows:

D = 100 mm (Outside diameter of pipe)

d = 90 mm (Inside diameter of pipe)

Δh = 2.25 mm (Total deflection of the tank)

E = 200,000 N/mm^2 (Young's modulus)

L = 1,500 mm (Length of pipe from the vessel to the first support point)

Use Equation (2) to determine F, the maximum pipe force allowable when Scale Capacity is applied to the scale:

$F \leq 0.1 \times 0.05 \times 20{,}000 \times 9.81$ N

$F \leq 980$ N

F cannot be greater than 980 N.

Use Equation (3) to calculate the actual force exerted by the pipe:

$$F_P = \frac{0.59 \times (1{,}000\times10^5 - 6{,}561\times10^4) \times 2.25 \times 200{,}000}{3{,}375\times10^6} = 2{,}705 \text{ N}$$

Since a pipe force of 2,705 N is greater than 980 N, it would not satisfy the requirement for a system with 0.05% System Accuracy. There are various possible solutions such as reducing the diameter and/or increasing the length of the pipe. A more practical approach may be to add an expansion joint to the pipe.

Select a lateral movement expansion joint that can accommodate the tank deflection Δh of 2.25mm in the above example; if a 100 mm expansion joint has a lateral spring rate of 45N/mm, its effect F_C on the tank can be calculated from Equation (4) as follows:

$$F_C = 45 \times 2.25 = 100 \text{ N}$$

This is well below 980 N and is acceptable. In many cases with multiple piping connections it will be found that the only solution is to use flexible pipes or expansion joints.

Piping Installation

This section shows ways to install piping in order to avoid scale performance problems.

Do not connect vertical pipes to a tank as shown in Figure 5-13a. As the tank is loaded and wants to deflect downwards, the pipe prevents it doing so to an extent that depends on the rigidity of the pipe and bracket. Any vertical force exerted by the pipe subtracts directly from that seen by the load cells and destroys accuracy. Vertical pipes must have a horizontal section as shown in Figure 5-13b to introduce flexibility. In general, all connections to the tank (pipes, hoses, conduit, ductwork, vents, etc.) should run horizontally from their first support to the tank. The design in Figure 5-13a is particularly bad if the tank is subject to temperature changes, for example, if a hot liquid is batched into the tank. In this case the tank and vertical pipe will expand and, reacting against the upper pipe bracket, exert a downward force against the weigh modules. Such forces can be greater than the weight to be determined thus destroying accuracy.

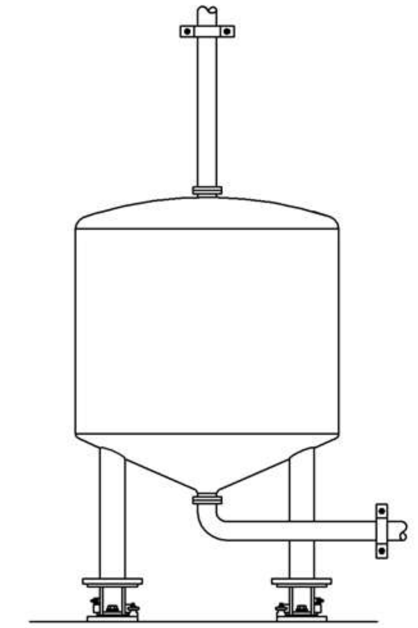


Figure 5-13a: Incorrect design of vertical pipe

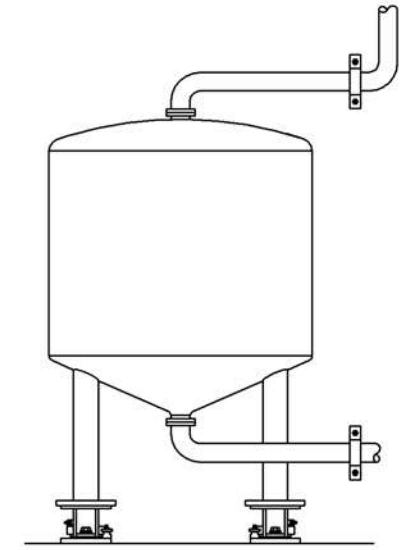


Figure 5-13b: Correct design of vertical pipe

Figure 5-14 illustrates an undesirable solution for attachment of vertical pipes where an expansion joint has been incorporated into a vertical pipe. In this position the expansion joint directly impacts the weight reading. To be effective at all such an expansion joint (or flexible hose) would need to be axially compliant, the extent required dependent on the scale capacity and accuracy required. It would need to be a perfect spring and any change in compliance due to aging would reflect directly in the scale reading. But the main problem is that, due to axial compliance, the expansion joint would act like a piston or hydraulic cylinder pushing and pulling the tank as a result of any internal pressure fluctuations. Pressure variations can be an integral part of the process or can happen unintentionally due to the normal filling and discharge operations, typically the time when weight readings must be taken. To avoid all such problems vertical pipes should be connected as shown in Figure 5-13b, and may be further improved greatly if necessary by the incorporation of flexible hoses or expansion joints in the horizontal piping sections.

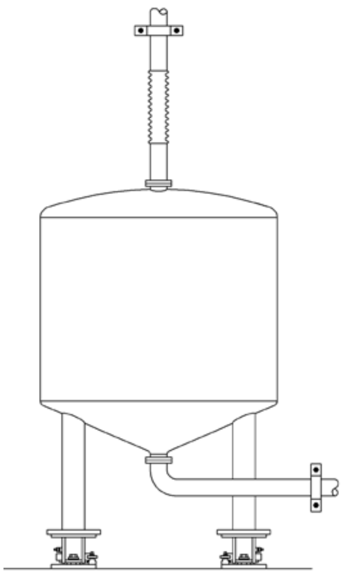


Figure 5-14: Undesirable Design of Vertical Pipe, especially if subject to pressure fluctuations

Instead of connecting multiple pipes individually to a tank, run them into a manifold with a single connection to the tank, as shown in Figure 5-15.

In general, minimize the number of pipes and their stiffness by, for example, reducing to a minimum the pipe diameter and wall thickness.

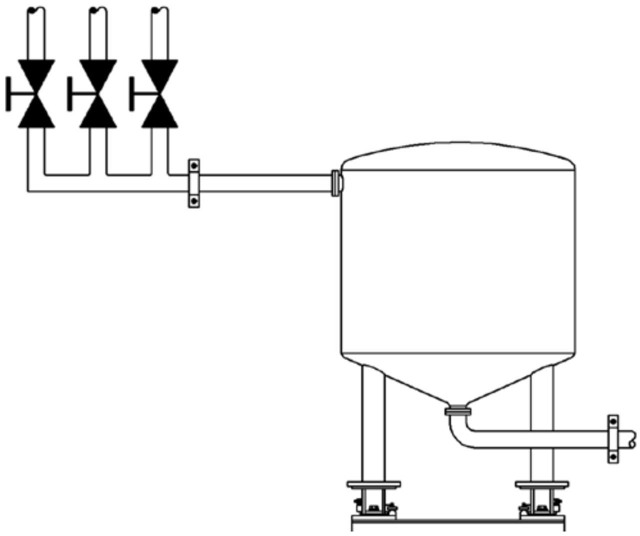


Figure 5-15: Use of a manifold to minimize connections to a tank scale

The greater the distance between the tank and the first pipe bracket the more flexible the piping connection will be (see Figure 5-16a).

Use a section of flexible hose or lateral movement expansion joint to minimize unwanted forces when the tank deflects (Figure 5-16b), as discussed previously. This is often the only way of satisfying the requirements outlined in the previous section, especially when multiple pipes must be connected to the tank.

A 90-degree bend in a horizontal run of pipe will make the piping more flexible (see Figure 5-17).

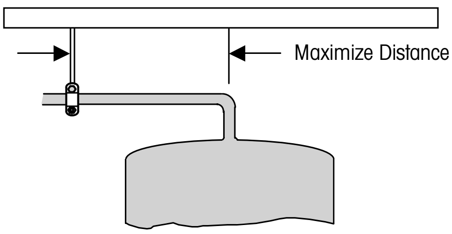


Figure 5-16a:
Distance Between Tank and Pipe Support

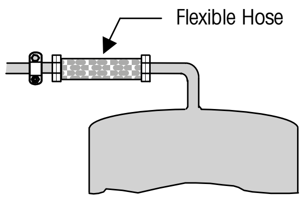


Figure 5-16b:
Piping with Length of Flexible Hose

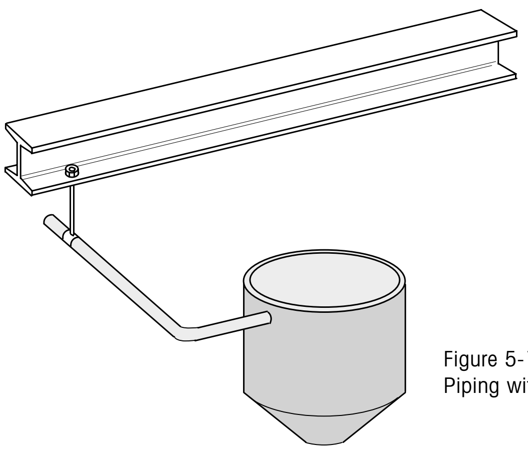


Figure 5-17: Horizontal
Piping with 90-Degree Bend

When a single discharge pipe is used by adjacent tanks (see Figure 5-18a), the weight of material being discharged from one tank can exert a downward force on the other tank. Instead, design the system so that the discharge piping from each tank is supported independently and does not interact with the other tank (see Figure 5-18b).

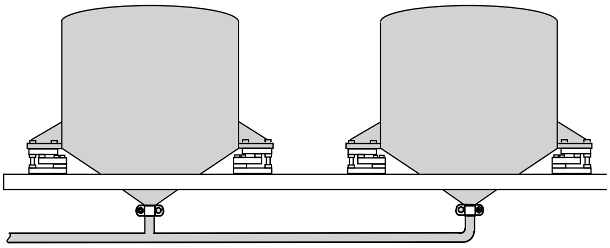


Figure 5-18a: Tanks with Single Discharge Pipe

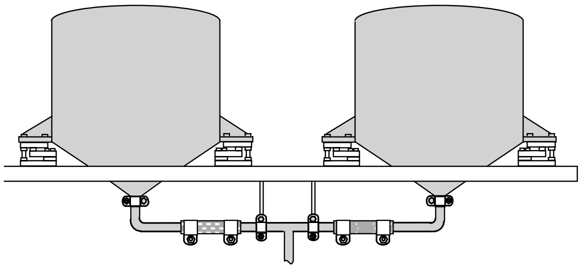


Figure 5-18b: Recommended Design for Single Discharge Pipe

Avoid the connection of pipes, and especially rigid pipes, directly between tanks, as shown in Figure 5-18c. As illustrated, the tank on the left has deflected under load, causing vertical forces in the common pipe. Avoid the connection of pipes to common supply, discharge or vent lines, as shown in Figure 5-18d. Again, the tank on the left has deflected causing vertical forces in the common overhead pipe. In both cases the weight registered on the tank at left will be reduced, while the tank at right will appear heavier. This is a form of crosstalk discussed in more detail in section Structural Support Guidelines.

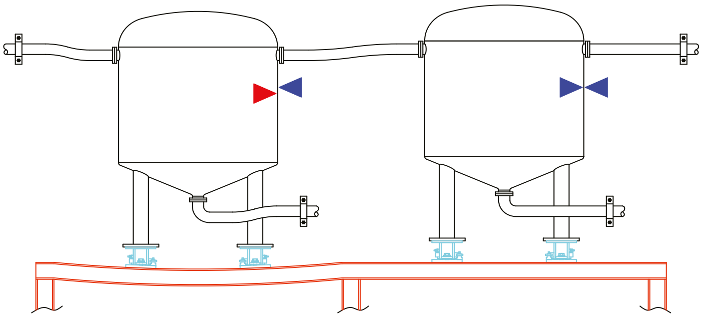


Figure 5-18c, crosstalk transmitted through directly connected pipe

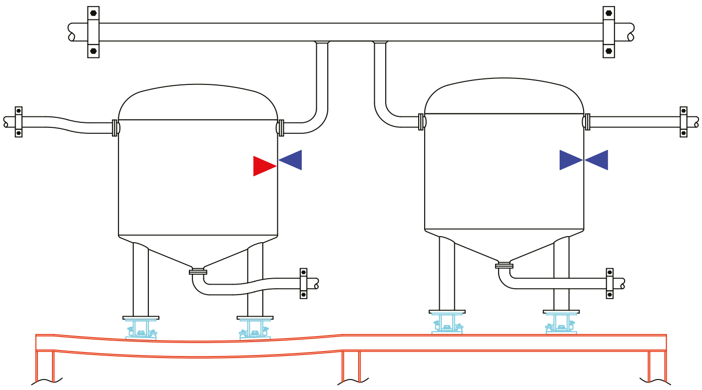


Figure 5-18d, Crosstalk transmitted through common overhead feed pipe.

Do not attach piping to a mezzanine, upper floor, or other structure that deflects independently of the tank (see Figure 5-19a). If possible attach piping to the tank's support structure so that the piping moves along with the tank (see Figure 5-19b).

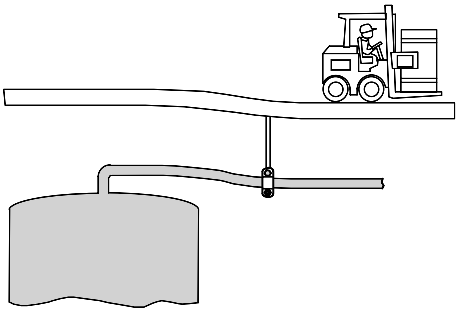


Figure 5-19a: Piping Supported by Upper Floor

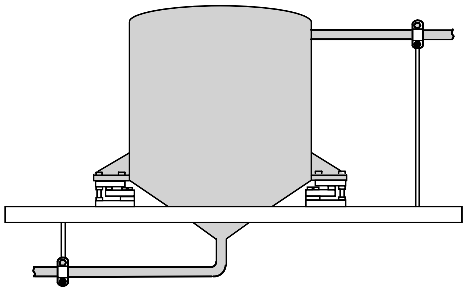


Figure 5-19b: Piping Attached to Tank's Support Structure

When possible, completely avoid rigid connections between piping and tanks. Note the clearance between the tank and inlet/outlet piping in Figure 5-20. A flexible boot is used to seal each connection.

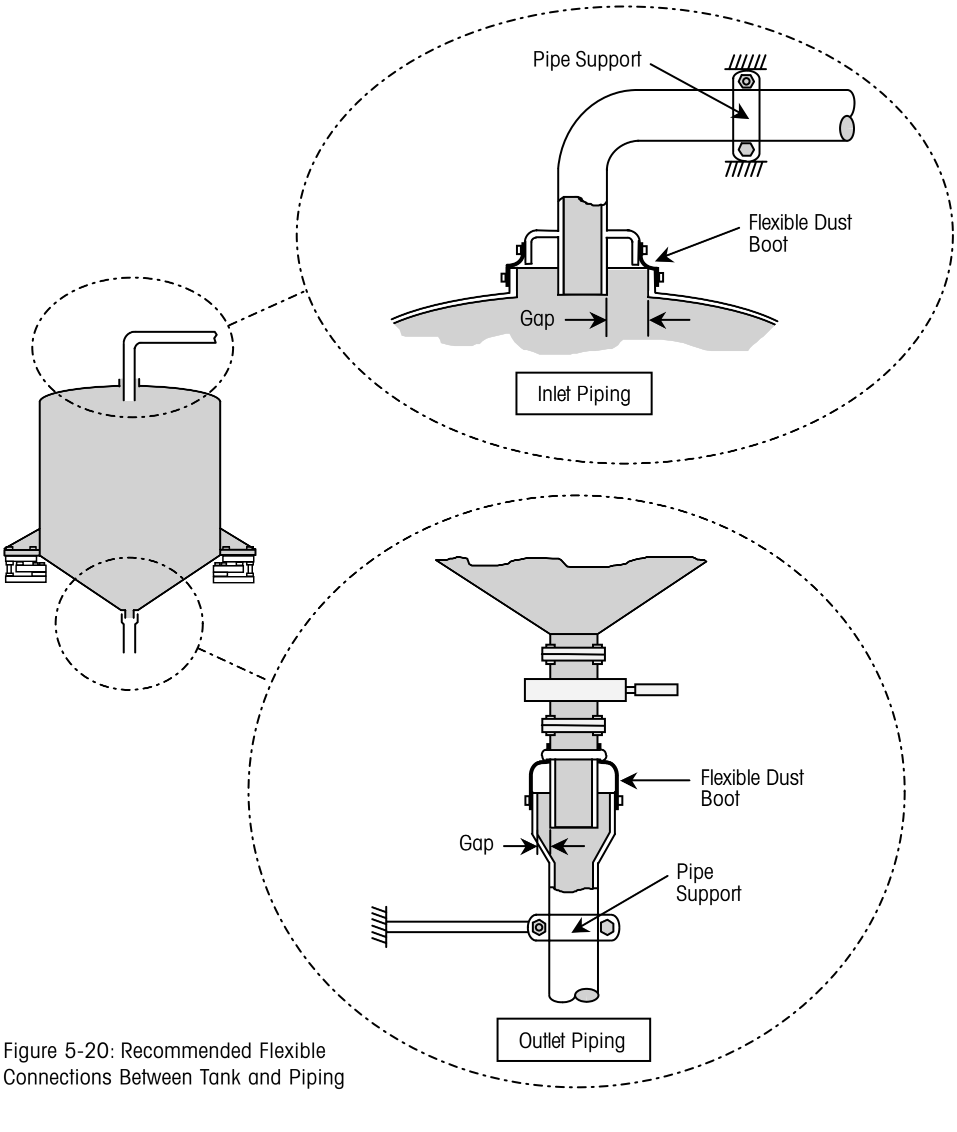


Figure 5-20: Recommended Flexible Connections Between Tank and Piping

Structural Support Guidelines

It goes without saying that a tank scale must be designed and supported in such a manner that it remains safe under the application of external forces such as those due to impacts from vehicles and from wind and seismic activity. It must also resist internal forces due to mixers and vibrators. While that is necessary, it may not be sufficient to achieve the accuracy and reliability expected of a tank scale. Some additional constraints to the design may be required, and that is the subject of this section.

Vertical Deflection and Crosstalk

The biggest issue in designing a tank or reactor scale is that its performance is very much affected by pipe forces which change scale sensitivity, see section Piping Design. As discussed, the key considerations are pipe stiffness and deflection of the scale's support structure. It will always be advantageous to minimize scale deflection as discussed below.

Crosstalk is a closely related topic associated with scale deflection and often involving pipe forces also. When the filling or emptying of one tank affects the weight display on an adjacent tank scale, we describe this as crosstalk. This is discussed below also.

These recommendations become more important the more of the following conditions apply to the particular scale:

- High Capacity. As scale capacity increases it becomes increasingly difficult to limit deflection.
- High scale performance needed.
- Multiple scales supported on the same structure. The more scales the more likely it is that they will share support members and be affected by crosstalk.
- High Pipe Forces. Pipe forces increase with the number of pipes, increasing pipe sizes and increasing pipe rigidity. A good example of a critical application is a pressurized reactor vessel which usually must have a plurality of rigid solid pipes.

The following figures show six mounting arrangements from best (Figure 5-21a) to worst (Figure 5-21f) in regard to overall deflection and potential for crosstalk. Figures 5-21b to 5-21f are drawn as tanks with support brackets supported by steel structures, but these recommendations apply equally to steel and concrete mezzanine floors and to tanks with legs on such supports.

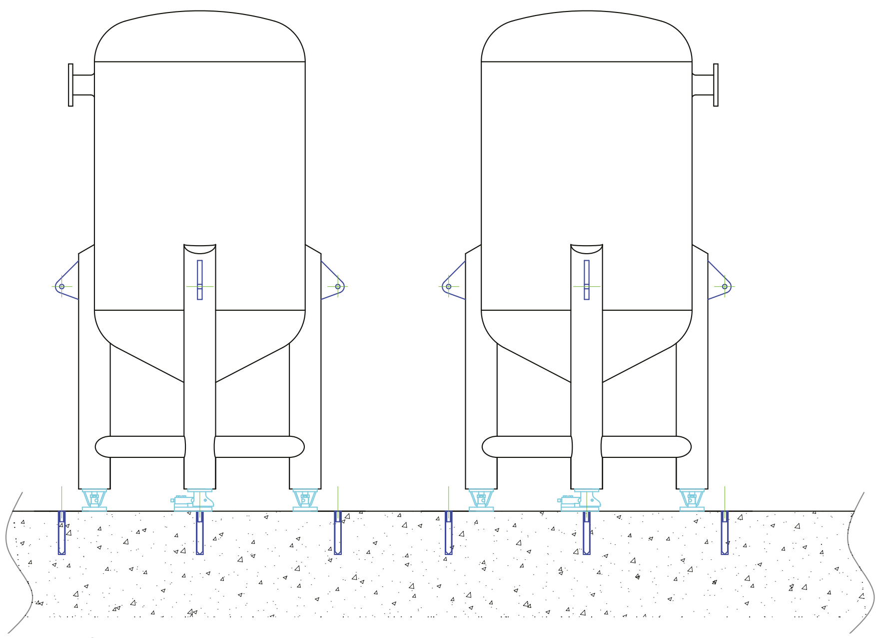


Figure 5-21a, Tanks mounted on a rigid foundation at ground level

Figure 5-21a shows tanks with cross-braced legs mounted on a concrete foundation at ground level. This will generally provide the least deflection and pipe influence, and the least crosstalk between adjacent tanks. This should be the arrangement of choice for high capacity and high performance tank and reactor scales.

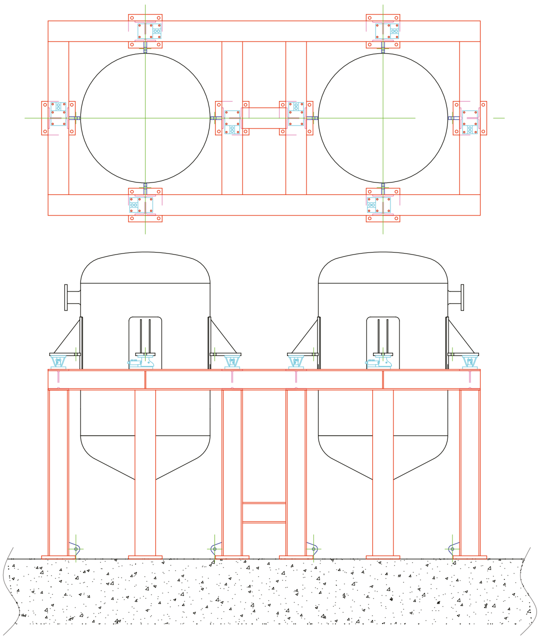


Figure 5-21b, Tanks mounted on a rigid frame with vertical column under each weigh module

Figure 5-21b shows tank scales mounted on a steel structure with a vertical column directly supporting each weigh module to eliminate any deflection in the horizontal frame. While there may be slightly more vertical deflection due to deformation of the support brackets and strain in the columns, this arrangement is not very different from that shown in Figure 5-21a. In addition, the tanks are supported independently, minimizing the potential for crosstalk.

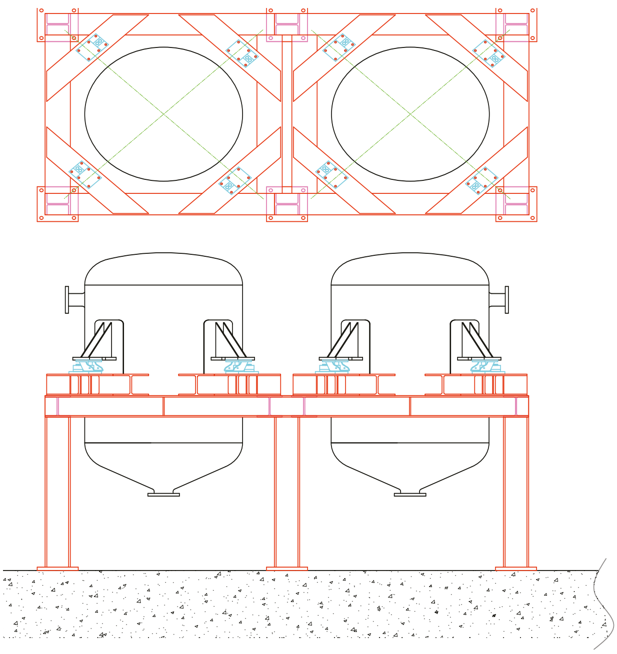


Figure 5-21c, Tanks mounted on horizontal beams near vertical columns

Figure 5-21c shows tank scales mounted on a steel structure with six vertical columns. Each tank is surrounded by a square frame with a structural member across each corner to support the weigh modules and to bring that point of support closer to the columns. There will be some bending in each of the horizontal members, so the arrangement is not as good as that in Figure 5-21b. The tanks share the two central columns but the tanks remain reasonably well isolated to minimize crosstalk.

Figure 5-21d, Tanks mounted at the center of horizontal beams.

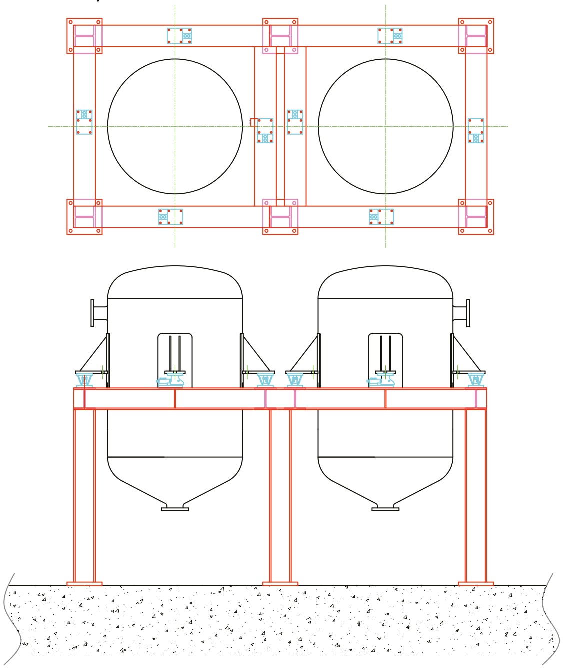


Figure 5-21d shows tank scales mounted on a steel structure with six vertical columns. Each tank is surrounded by a square frame with the weigh modules supported at the center of the beams. These beams will bend and result in more deflection compared to Figure 5-21c above. The tanks share the two central columns but the tanks remain reasonably well isolated to minimize crosstalk.

Figure 5-21e, Tanks mounted at the center of horizontal beams, one shared.

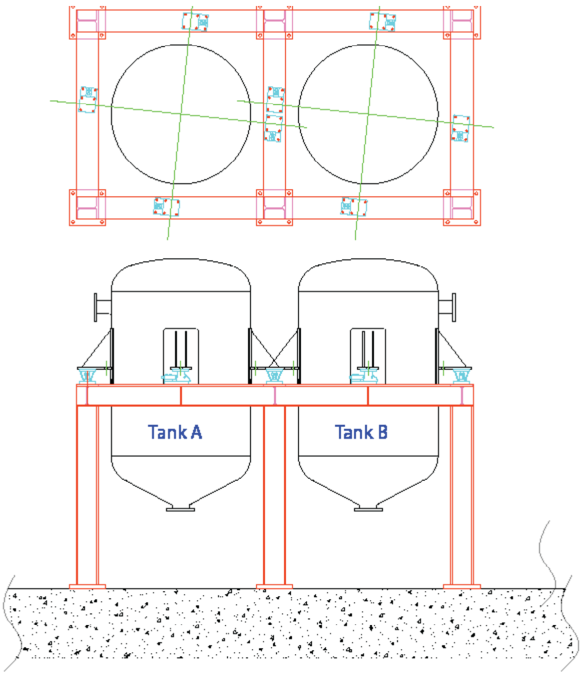


Figure 5-21e is similar to the previous example but the tanks have been rotated somewhat to offset the adjacent weigh modules, allowing them to be mounted on a common central beam. Therein lies the weakness of this arrangement, that beam carries double the load with approximately double the deflection when both tanks are filled. This increases the overall deflection and piping effect. Additionally crosstalk becomes a real concern.

Referring to Figure 5-21e above, here is an example to illustrate the problems related to crosstalk. If you start with empty tanks and then fill tank A, its four support beams will deflect equally and tank A will move down uniformly; the deflection is undesirable but it is OK so far with regard to crosstalk.

If you then fill tank B, the shared beam will deflect further thus affecting the weight displayed on tank A in several ways potentially:

1. The weight will be redistributed between the four weigh modules causing additional overall downward deflection of the tank. This transfers load from the weigh modules to the pipes causing its weight display to decrease. The extent of this will be dependent on the amount of additional deflection and the stiffness of A's pipes.
2. The weigh modules on one diagonal will carry additional load while those on the other diagonal will carry less. This redistribution of load could cause the weight reading to increase or decrease. This is because of the tolerance on the load cells' Rated Output (typically 0.1% for METTLER TOLEDO's load cells) and the fact that shift (eccentricity) adjustment is typically not performed on tank scales. Also, in an extreme case this could cause load cells to be overloaded and damaged. These points apply only to tanks with four or more weigh modules; avoid problems by mounting on three weigh modules, when possible.
3. The tank will tilt slightly causing its center of gravity to move laterally, this will change the load distribution on the weigh modules with potential for the problems described in 2. above. This would not be a problem on the tank illustrated in 5-21e with the weigh modules located very close to the tank's center of gravity, something that is desirable generally. It could be a problem on tall slender tanks mounted close to their base on a flexible structure.

Crosstalk goes both ways. In the example above tank B was filled to a certain weight and was assumed to be correct, but its displayed weight may well change as tank A is emptied.

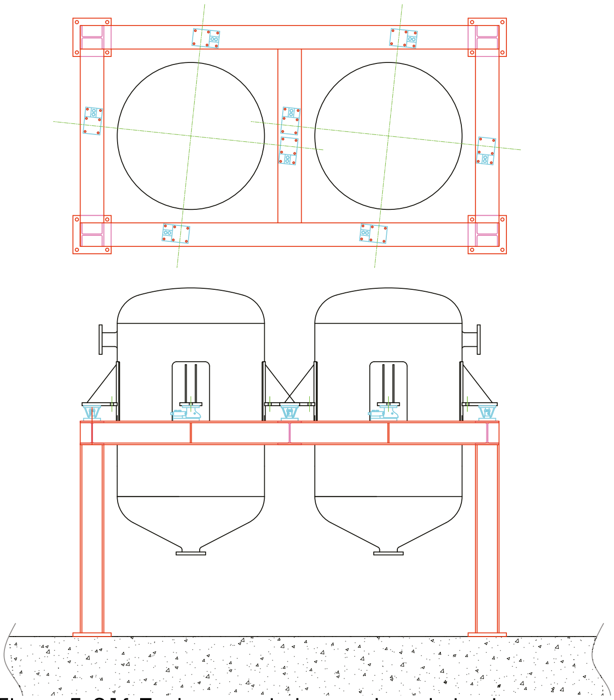


Figure 5-21f, Tanks mounted on a shared structure.

Figure 5-21f is very similar to Figure 5-21e but with one crucial difference, the central columns have been removed leaving the horizontal frame supported at the four corners only. This increases the overall deflection of the tanks, the tipping of the tanks and crosstalk between them. In this situation all of the problems described for Figure 5-21e above apply but are amplified. Matters become more complex and potentially worse when more than two tanks are mounted on such a shared structure.

Localized Support Bending

As well as gross downward deflection of a scale, we must also pay attention to localized bending or distortion of the support plates or structures at the immediate interface to weigh modules. For one thing this would contribute to the overall downward deflection of the scale, but it also changes the load introduction conditions at the load cell, leading to cosine errors and/or extraneous forces described in section Applying Force to Load Cells. Because load cells deflect by as little as 0.010 inches [0.25 mm] at rated capacity, you can appreciate that they are very sensitive to localized bending of interface surfaces, affecting linearity, hysteresis and repeatability. When designing a weigh module's support structure, you should follow these guidelines:

- The support brackets on the side of a tank (above a weigh module) should not bend or twist by more than 0.5 degrees out of level on application of scale capacity, as in Figure 5-22a. Reduce to the minimum the projection of the bracket from the tank wall to reduce bending moments. Reinforce the tank wall as necessary to control elastic buckling.
- The support structure or plate under a weigh module should not bend or twist by more than 0.5 degrees out of level on application of scale capacity, as in Figure 5-22c. Add stiffener plates to reinforce flanges as in Figure 5-26c.

Note:
± ½ degree out of horizontal is equivalent to a 1/32 inch rise or fall for every 4 inches of run. For example, if a base plate was 8 inches long, it could rise or fall by (8/4) x 1/32 = 1/16 in maximum over its length.
In metric units ± ½ degree is equivalent to 1mm rise or fall for every 125mm of run. For example, if a base plate was 250mm long, it could rise or fall by (250/125) x 1 = 2mm maximum over its length.

The following three figures show how support deflection affects a weigh module.

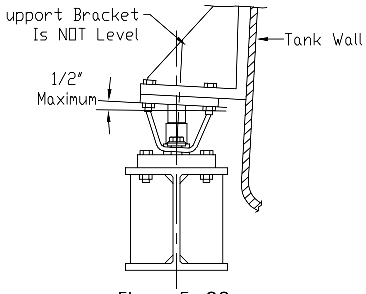


Figure 5- 22a

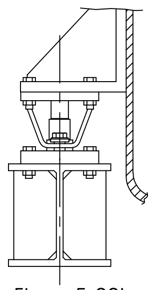


Figure 5-22b

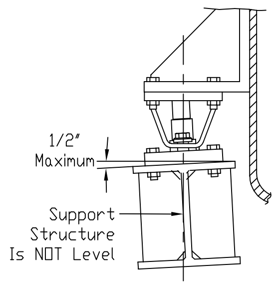
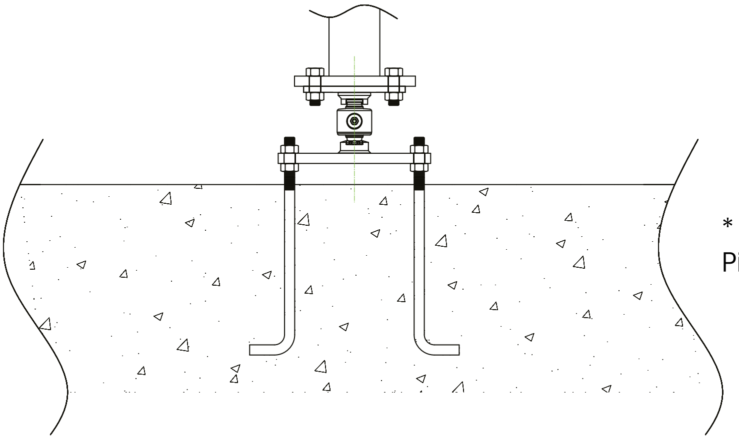


Figure 5-22c

* new picture
Picture 5&6 (1).pdf

- Figure 5-22a: Support bracket is out of level, applying side forces to the load cell.
- Figure 5-22b: Support bracket and support structure are aligned properly.
- Figure 5-22c: Support structure is out of level, applying side forces to the load cell.

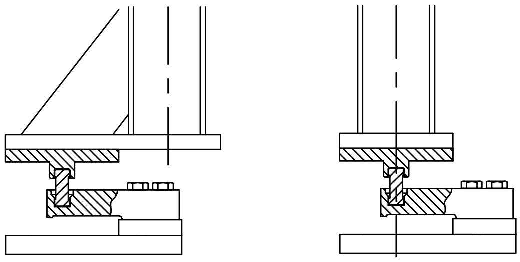
Loads are transmitted over a small area of contact between the weigh module top plate and load cell, and often also between the load cell and base plate below. Figure 5-23 shows PinMount with detail removed for clarity, showing the load path along the center line. Load transmission is concentrated at the center of the top and base plates over the relatively small area of the receivers. Illustrated is a typical installation method where the nuts under the base plate are used to adjust weigh module height for correct weight distribution and to level the plate. Before the scale is first loaded, it is critical that the space under the base plate be shimmed or filled with a suitable grout; it is especially important that the area under the receiver is supported. Failure to do so will lead to extra scale deflection and will quite likely damage the weigh module. The same applies to the interface between the tank leg and weigh module top plate. If the foot plate on the leg is not horizontal then the space between the plates should be shimmed, again paying particular attention to filling the area directly above the upper receiver.



* new picture
Picture 5-15.ai

Figure 5-23, Installation of PinMount, detail removed to clarify load path through load cell

The weigh module must not be positioned as shown in Figure 5-24a to avoid buckling the tank leg, and bending of the plate above the weigh module out of a horizontal plane. Figure 5-24b illustrates correct positioning, the weigh module is positioned so that the point of support to its top plate is on the center line of the leg.



Incorrect Weigh Module Position
Figure 5-24a

Correct Weigh Module Position
Figure 5-24b

* new picture
Picture 5&6 (1).pdf

In some cases, a tank's legs will spread or buckle as weight is added to the tank (see Figure 5-25a). Such legs should be braced to keep them rigid (see Figure 5-25b).

As discussed in section **Applying Force to Weigh Modules,** weigh modules must be installed between a rigid foundation or structure below, and a rigid scale above

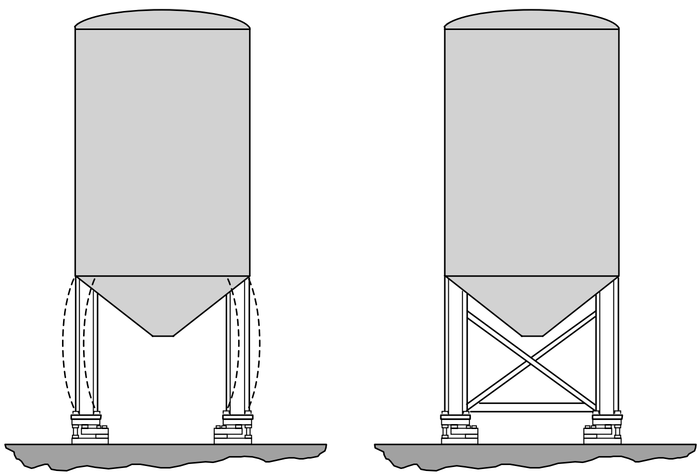


Figure 5-25a:
Deflection of Tank Legs

Figure 5-25b:
Tank Legs Braced

Avoid splayed legs as shown in Figure 5-25c. Remember that weigh modules in normal weighing mode do not restrain lateral top plate movement, not until the top plate has moved by 0.12 to 0.25 inches [3 to 6 mm], see section **Applying Force to Weigh Modules**. When the tank in Figure 5-25c is filled, the legs will be subjected to a bending moment tending to buckle the underside of the tank. This will allow the legs to spread thus changing the load introduction to the load cells and contributing to vertical deflection of the tank. Brace between the legs or use conventional vertical legs instead.

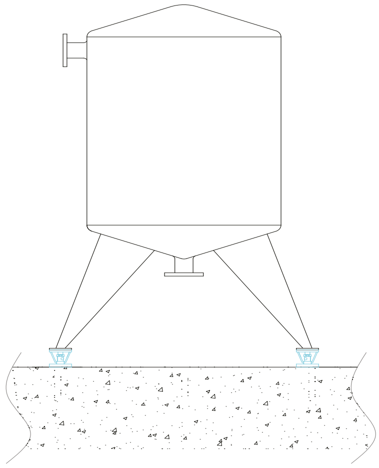


Figure 5-25c: Tank Legs Splayed

The center line of load application on a load cell should align with the center line of the weigh module's support beam. Ideal installations for a compression weigh module and tension weigh module are shown in Figure 5-26a and Figure 5-26b.

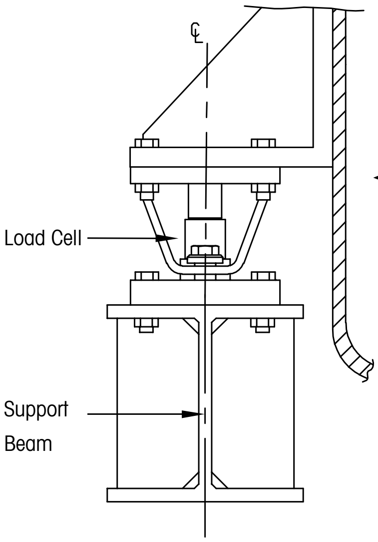


Figure 5-26a:
Compression Weigh Module

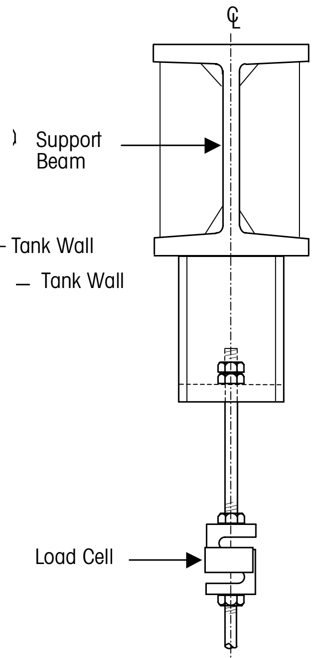
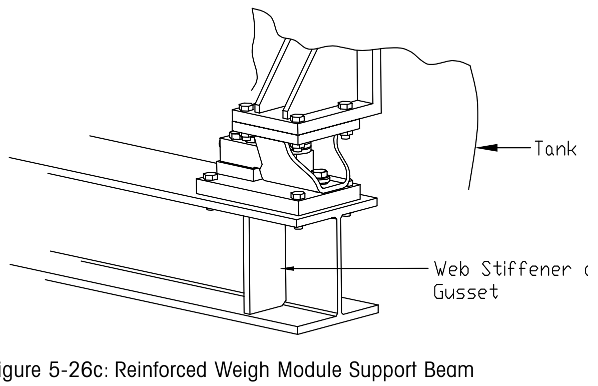


Figure 5-26b:
Tension Weigh Module

* new picture
Picture 7(1).pdf

Add web stiffeners or gussets if necessary to prevent the beam from twisting under load (see Figure 5-26c).



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Picture 8 (1).pdf

Figure 5-26c: Reinforced Weigh Module Support Beam

Stiffening Support Structures

The vertically downward deflection of a tank scale should be reduced consistent with guidelines in section Piping Design. Any remaining deflection should be uniform across all support points, as shown in Figure 5-27.
See Figure 5-21e for discussion of the consequences of non-uniform deflection.
Metal support structures tend to bend or deflect as the amount of weight placed on them increases. Too much de-

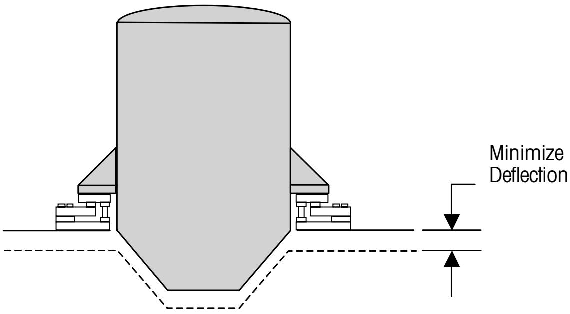

Figure 5-27: Weigh Module Base Support Structure Deflection

flection can affect the accuracy of a tank scale. The greatest potential for deflection occurs when a weigh module is mounted at the middle of a support beam's span. Figure 5-28a shows how a support beam can deflect when a weigh module is mounted at mid-span. If this type of arrangement cannot be avoided, you should reinforce the support beams to minimize deflection. Figure 5-28b and Figure 5-28c show typical reinforcement methods.

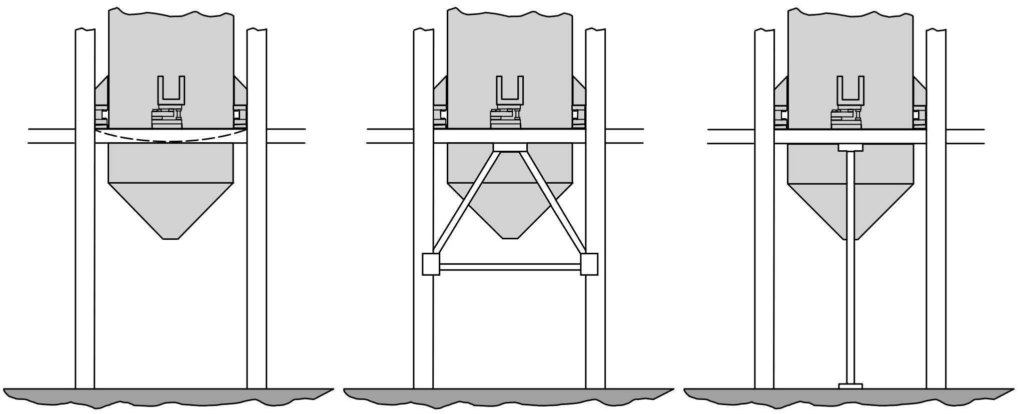

Figure 5-28a Figure 5-28b Figure 5-28c

Structural Beam Support

A better way to reduce deflection is to mount weigh modules near grounded vertical columns instead of at the center of horizontal support beams. Be sure to support all weigh modules with the same size structural beams to prevent differential deflection, which can cause *repeatability or zero-return problems. Figure 5-29a shows a recommended arrangement with weigh modules mounted near vertical beams, and Figure 5-29b shows weigh modules mounted at the center of horizontal beams which is not recommended.

*text removed: non

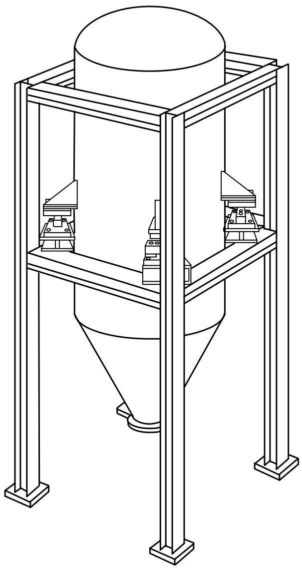

Figure 5-29a:
Recommended

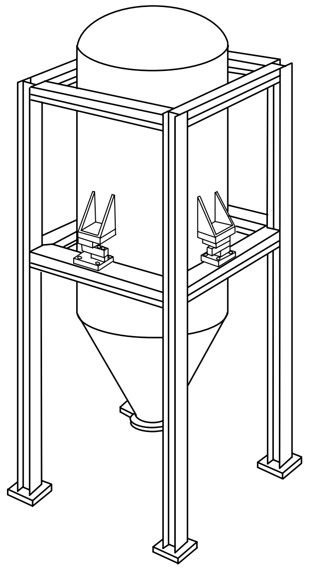

Figure 5-29b:
Not Recommended

Figure 5-30 and Figure 5-31 show details of methods used to mount weigh modules near grounded vertical columns.

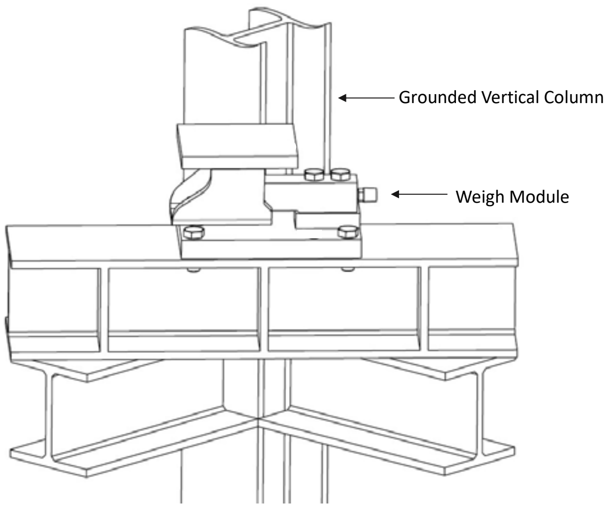

Figure 5-30: Structural Beam Support

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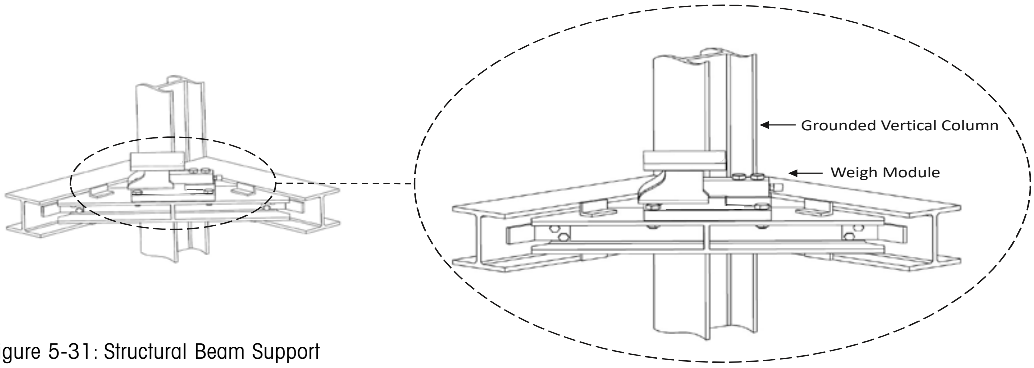

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Figure 5-22 (1).pdf

Figure 5-31: Structural Beam Support

Additional Vessel Restraint Methods

Most METTLER TOLEDO compression weigh modules are designed to be self-checking and provide adequate protection against tipping. But in applications with a potential for excessive wind or seismic load forces, additional restraint systems are often needed. For suspended tension weigh module applications, a safety restraint system is always needed to catch the tank in case its suspension components fail.

Check Rods

Check rods are used to limit a tank's horizontal movement so that it will not tip or rotate. They should be positioned at or above the center of gravity of the full tank. Figure 5-32 shows recommended check rod arrangements. Note that the check rod is tangential to the tank, with a gap between the check rod and the bracket on the tank. This enables the check rod to restrain the tank while allowing for minor thermal expansion and contraction. Several such check rods will be required to fully restrain the tank. When check rods are installed in a perfectly horizontal position, they do not create vertical forces that will affect the scale's weight readings.
Note that the check rods described here are loose on one end at least and are intended to restrain the tank under rare loading conditions; they are not intended to stabilize a dynamic tank vibrating, for example, due to the effects of rotating equipment.

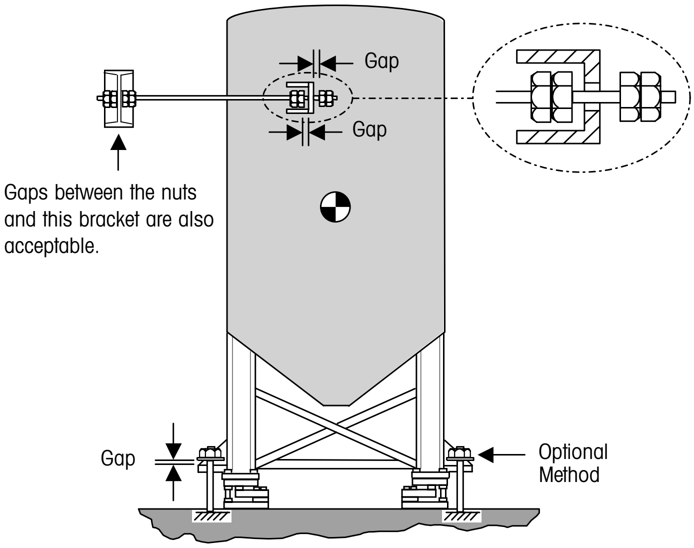


Figure 5-32: Tank with Check Rods

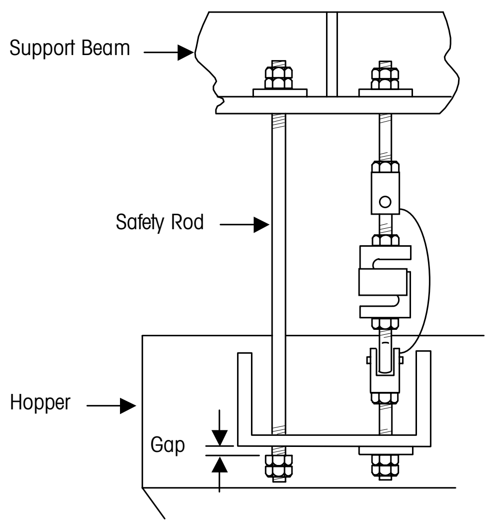


Figure 5-33: Tension Weigh Module with Safety Rod

Safety Rods

Any tank that is suspended by tension weigh modules should have a secondary safety restraint system. Safety rods must be strong enough to support the filled tank in case the primary suspension system fails. For most applications, you would install one vertical safety rod next to each tension weigh module (see Figure 5-33). Fit each safety rod through an oversized hole in the bracket so that the rod does not influence the live weight readings. Horizontal check rods or bumpers can be used around the perimeter of the tank to keep it from swaying.

Provisions for Calibration

Unfortunately scale calibration is often an afterthought and not considered until after scale installation. Scales of all kinds must be calibrated at installation and usually at intervals during their lifetime. Tank, reactor, hopper, etc. scales are no exception and in fact prove to be more difficult to calibrate because of their capacity, location and the fact that typically there is no flat surface upon which to load test weights. It will be much easier to make provisions for calibration during the design phase, and lifting lugs judiciously placed can often be used for both purposes with little or no additional expense.

Test Weight

If you are going to use test weights to calibrate a tank scale, you will need some way to hang the test weights from the tank. In most cases, this can be done with some type of mounting lugs spaced evenly around the tank. Figure 5-34a shows a mounting lug with a test weight hanging from it. Use a hoist for raising/lowering the weight.

It is important that lugs are placed symmetrically around the tank, for example three lugs separated by 120 degrees or 4 lugs separated by 90 degrees. Hang the same amount of weight from each lug. Another method is to provide a temporary or permanent platform on which test weights can be piled symmetrically vis-a-vis the vertical center line of the tank. A temporary platform is sometimes created by laying wooden planks across the horizontal bracing between legs

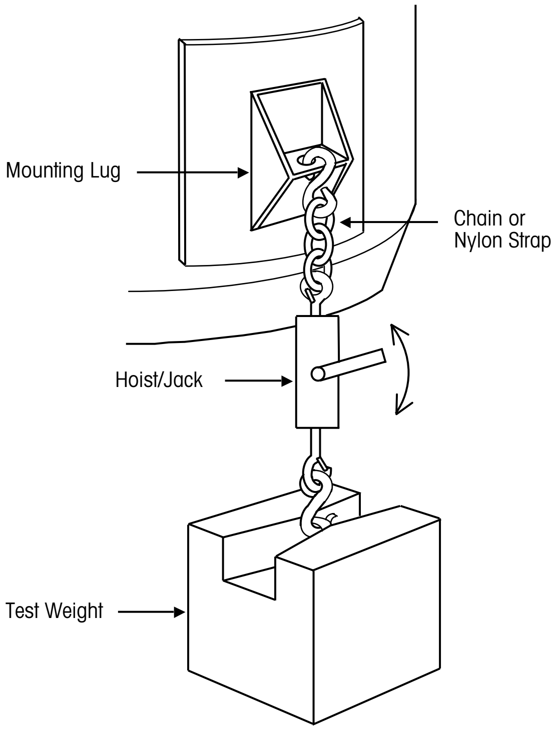


Figure 5-34a: Mounting Lugs for Test Weight

RapidCal™

Figure 5-34b shows a tank scale equipped for METTLER TOLEDO's RapidCal™ calibration system, while 5-34c shows the equipment installed temporarily for the calibration process. Lugs have been added to the tank legs while sub-plates have been fitted under each weigh module. The RapidCal equipment is attached between the lugs and threaded holes in the sub-plates. Many different configurations are possible to suit different tanks and installation arrangements, including tension-mounted tanks. Request a RapidCal™ Engineering Recommendation package for complete details.

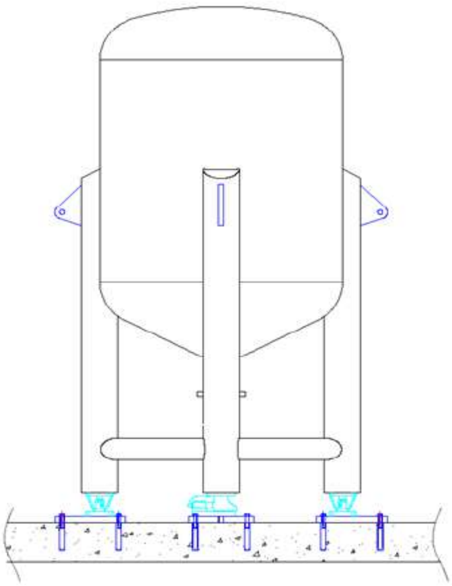


Figure 5-34b: Tank equipped for RapidCal™

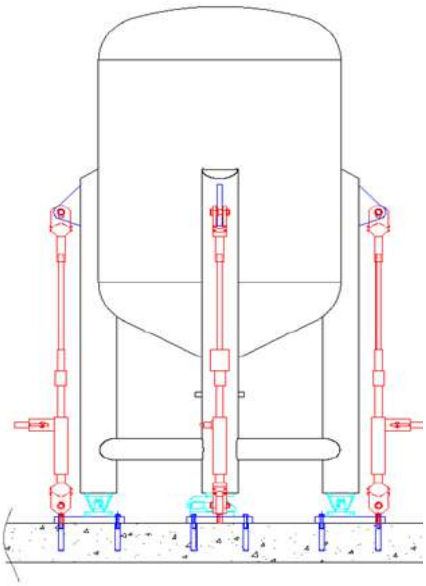


Figure 5-34c: Tank during calibration process

Electrical Wiring

Analog Systems

Analog load cells are supplied with an integral cable and how they connect to the terminal depends on the number of load cells in the system.

One load cell: Its cable can connect directly to the terminal.
Two to four load cells: This will require a junction box to sum the signals before transmission to the terminal, see Figure 5-35a.
Five to eight load cells: Two junction boxes with auxiliary (AUX) functionality will be required, connected in series as shown in Figure 5-35b.

Nine plus load cells: There is no limit to how many auxiliary junction boxes that can be connected in series, however, the terminal will have a limitation on how many load cells it can power.

To complete these junction box systems some additional cables are required as follows:

- A home run cable connects from the terminal to the first junction box. Always use a 6-wire cable and the SENSE function of the terminal so as to avoid introduction of temperature sensitivity.
- Auxiliary cables make the connection from the first to subsequent boxes, as required. Minimize the length of auxiliary cable to avoid introducing a temperature sensitivity. The auxiliary cable is usually of the same type as the home run cable.

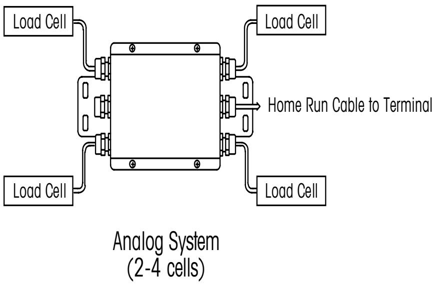


Figure 5-35a: Analog Junction Box

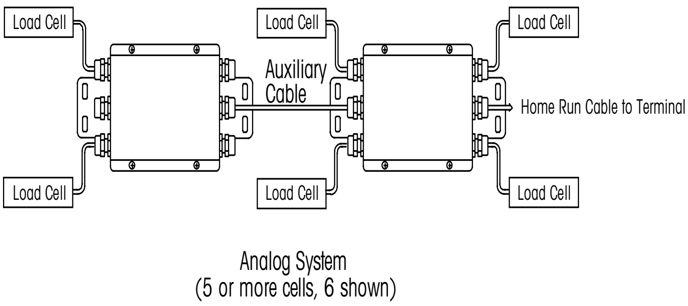


Figure 5-35b: Analog Junction Boxes connected in Series

Junction Boxes

The junction box is a key component in multi-load cell systems and the typical junction box provides the following functionality:

- At the most basic level it provides a convenient means of wiring the load cells.
- It connects the load cells' excitation lines in parallel across the terminal's excitation lines.
- It connects the load cells' output lines in parallel and provides a summed signal to the terminal.
- It allows eccentricity (or shift) adjustment. That is the process by which resistance is inserted in the circuit so that all load cells provide the same output signal for a given load.
- It provides the means for connection of the home run cable SENSE lines from the terminal. In this way the terminal can sense the actual excitation voltage arriving at the junction box and can compensate for thermal effects on the home run cable.
- As noted above, some junction boxes have an auxiliary function which allows multiple boxes to be connected in series.

The junction box is critical to scale metrology as it is handling very small analog signals in the first place, but also because it has resistors in that critical circuit. The temperature sensitivity and long-term stability of the resistors is critical. Take care in positioning the junction box to avoid temperature changes due to conducted or radiant heat, and to avoid moisture ingress as far as possible.

In harsh environments, load cell cables should be protected by running them through conduit. METTLER TOLEDO supplies a large analog junction box that is equipped with 1/2-inch conduit fittings (see Figure 5-36). The box is large enough so that excess cable can be coiled and stored inside the box.

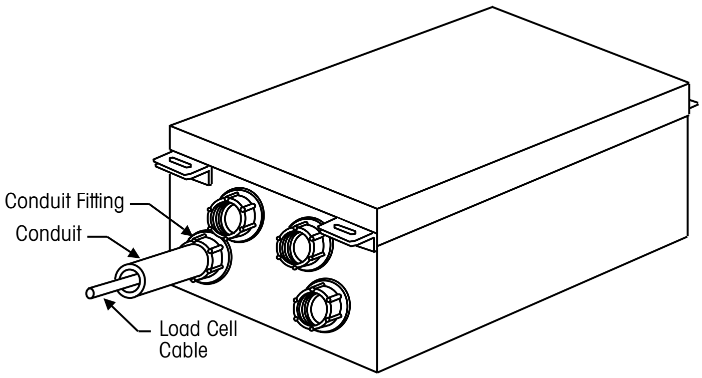


Figure 5-36: Large Analog Junction Box with Conduit Fittings

Load Cell Cables

Normally, each load cell is supplied with a standard length of cable. Do not lengthen or shorten load cell cables in the field. **Changing the length of a load cell cable will affect the output signal from the load cell and its temperature compensation**. If a cable is too long, simply coil the excess cable and place it in or near the junction box. You can order junction boxes in sizes that are large enough to hold coiled cables. Never attach excess cable to a live portion of the weighing system. Nonstandard lengths of cable can be ordered for applications that require them.

Home Run Cables

A home run cable transmits the summed load cell signal from the junction box to the terminal. To provide accurate weight readings, a scale must be able to distinguish between electrical signals that differ by millionths of a volt. So small amounts of noise introduced through the cables can cause weighing errors. Common sources of noise are radio frequency (RF) and electromagnetic (EM) radiation produced by power cords, power lines, motors, or cellular phones.

To reduce radio frequency and electromagnetic interference, install a ferrite ring over the home run cable at the terminal. It should be placed inside a harsh enclosure or as close as possible to the connector on a panel-mount enclosure. Wrap the home run cable conductors and the shield ground wire around the ferrite ring four times (see Figure 5-37). Keep the ferrite ring as close as possible to the point where the cable enters the enclosure.

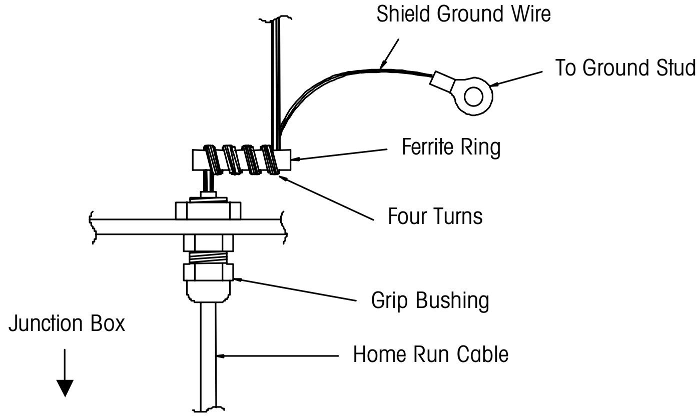


Figure 5-37: Ferrite Ring Apparatus

The following installation guidelines will also help prevent electrical interference:

- Install cables at least 12 inches [300 mm] from power lines.
- Fully insulate and ground cables to prevent them from picking up unwanted noise.

Cables are often exposed to mechanical damage or damage caused by water or chemicals. To protect cables from damage, encase them in flexible conduit. FEP/PTFE coatings are available to protect cables in corrosive environments.If a mixing agitator is attached to a tank, keep enough slack in the power supply cables to prevent live-to-dead load interference.

We recommend using a dual-shield cable design to protect the signal from electromagnetic and radio frequency interference. A cross section of this type of home run cable is shown in Figure 5-38.

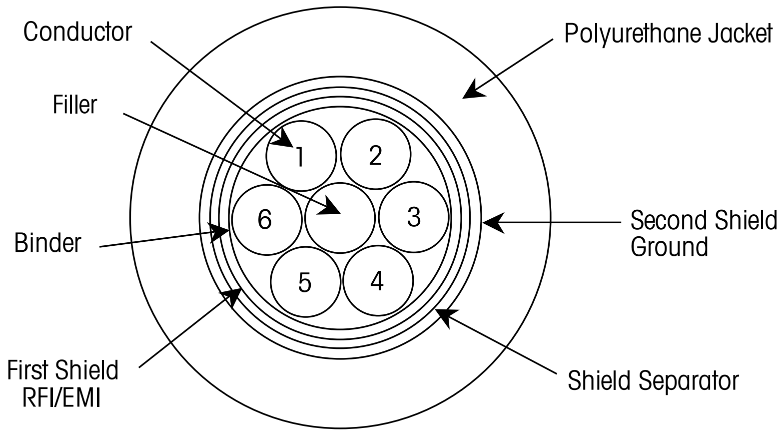


Figure 5-38: Cross Section of Dual-Shield Home Run Cable

Maximum Number of Load Cells

Multiple load cells are connected in parallel between the terminal's plus and minus excitation lines. The more load cells that are connected, the lower the resistance and the greater the power draw on the terminal. All terminals have a limit that must not be exceeded, otherwise it may be damaged.

When several load cells are connected in parallel, the scale's resulting input resistance is referred to as the Total Scale Resistance (TSR), and can be calculated as follows:

$$\text{TSR } (\Omega) = \frac{\text{Load Cell Nominal Bridge Resistance } (\Omega)}{\text{Number of Load Cells}}$$

It is customary to use the load cell's nominal bridge resistance, common values being 350, 700 and 1000 Ω.

For example, typical double ended shear beams have a 700 Ω nominal bridge resistance; a scale made up of eight such load cells would have a TSR of 700/8 = 87.5 Ω.

Terminals are usually specified in terms of the maximum number of 350 Ω load cells that can be safely connected. Table 5-1shows some typical terminal specifications and the equivalent minimum TSR that may be connected.

Table 5-1 Terminal specifications for Load Cell Power Capabilities

Terminal can power:	**Corresponding TSR**
Max 4 x 350 Ω	Min 87 Ω
Max 6 x 350 Ω	Min 58 Ω
Max 8 x 350 Ω	Min 43 Ω

If it's specified that a terminal can power a maximum of 4 x 350 Ω load cells, then clearly it can power up to and including four such load cells. However, from the example above and Table 5-1 it is clear that this terminal can also power eight 700 Ω load cells.

Maximum Home Run Cable Length

The length of the home run cable must be limited to avoid excessive voltage drop between the terminal and the first junction box. The recommended max home run cable length is a function of the Total Scale Resistance (TSR) and the cable gage (cross-sectional area), the lower the TSR the shorter the cable must be.
Calculate the TSR as explained in the previous section then you can see the max recommended cable length in Table 5-2. You can also pick directly from Table 5-2 using the number of load cells in the system.

Table 5-2: Relationship between TSR and Recommended Max Home Run cable length

TSR Ω	**Corresponding No. of Load Cells**			**Max Home Run cable length, ft (m)**		
	350 Ω*	700 Ω*	1000 Ω*	24 Gage (0.25 mm2)	20 Gage (0.5mm2)	16 Gage (1.5mm2)
350	1	2	2	800 (240)	2400 (730)	4000 (1200)
117	3	6	8	265 (80)	800 (240)	1330 (400)
87	4	8	11	200 (60)	600 (180)	1000 (300)
43	8	16	22	100 (30)	300 (90)	500 (150)
35	10	20	28	70 (21)	190 (58)	350 (105)

*Load Cell Nominal Bridge Resistance

POWERCELL® Systems

In contrast to analog systems, POWERCELL® systems do not require junction boxes as the load cells are connected in a daisy-chain, as shown in Figure 5-39. A home run cable connects the Terminal to the first load cell and load cell-load cell cables connect between load cells to complete the daisy-Chain. POWERCELL® load cells on the same daisy-chain can be grouped to create several scales; this is configured on the Terminal. The maximum number of the load cells, the length of the home run cable, and the total length of the chain are interdependent. For details see the POWERCELL® load cell documentation.

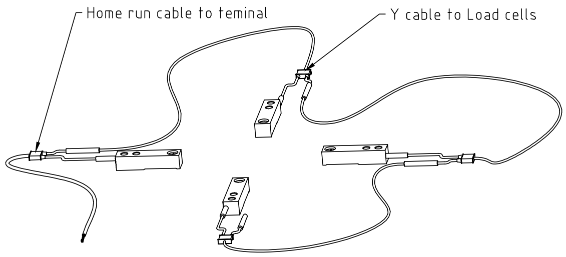
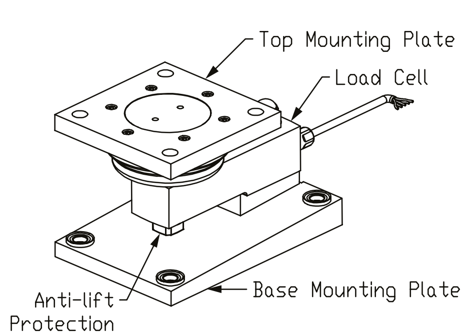


Figure 5-39:Powercell® System

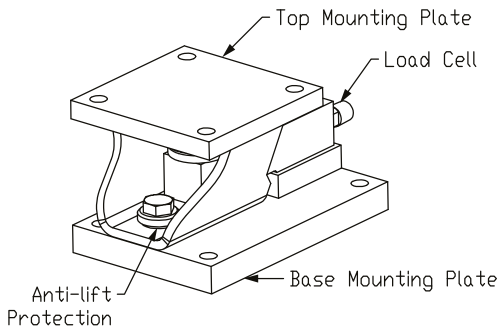
6. Compression Weigh Modules

Introduction

This chapter provides general information about how to select and install compression weigh modules. Each application has unique requirements and should be planned by a qualified structural engineer. When installing weigh modules, refer to the Installation and Service Manual for the specific model. Examples of METTLER TOLEDO compression weigh modules are shown below.

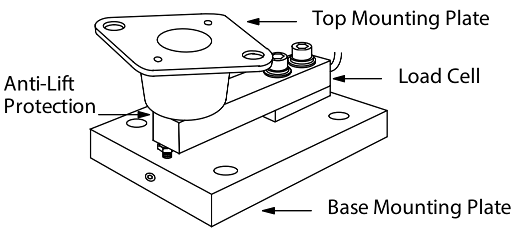


SWB805 Hygienic Weigh Module
(Self-Aligning Suspension)

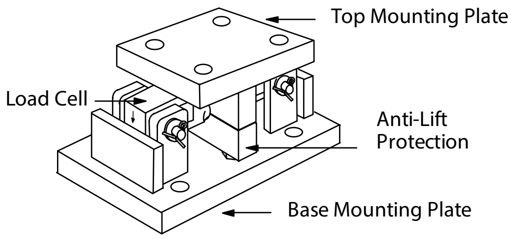


MultiMount Weigh Module
(Self-Aligning Suspension)

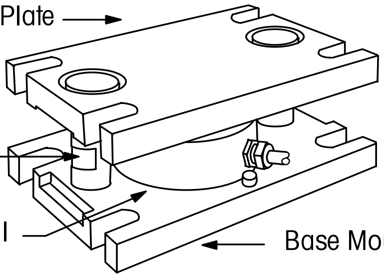
*new image:
6 Introduction_a.pdf



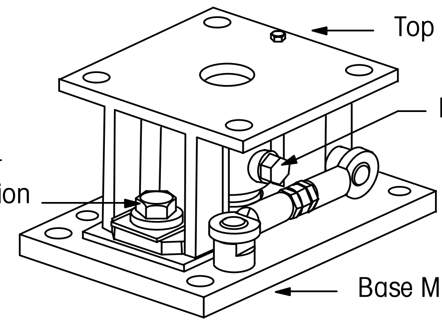
VLM2 Weigh Module
(Rigid Suspension)



VLM3 Weigh Module
(Sliding Suspension)



RINGMOUNT Weigh Module
(Self-Aligning Suspension)

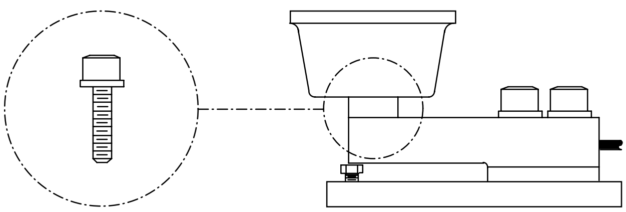


PINMOUNT Weigh Module
(Self-Aligning Suspension)

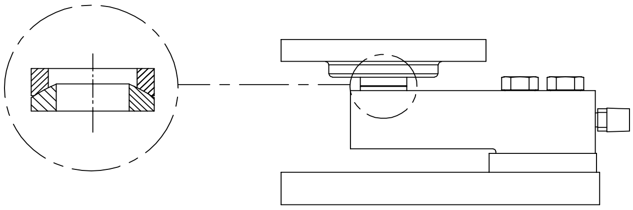
Static versus Dynamic Loading

When selecting weigh modules for an application, it is important to consider how the load will be applied to the load cells. Most weigh module applications on tanks, hoppers, and vessels are subject to static loading. Under normal operation with static loading, little or no horizontal shear force is transmitted to the load cells. Applications such as conveyors, pipe racks, mechanical scale conversions, and high-powered mixers or blenders are subject to dynamic loading. With dynamic loading, the way in which products are placed on a scale or processed transmits horizontal shear forces to the load cells.

A weigh module's suspension controls how the load is transmitted from the tank or weighbridge to the load cell. When selecting weigh modules, it is important to match the suspension to the type of loading that will be encountered. METTLER TOLEDO offers weigh modules with the following types of suspensions:



Rigid Suspension: Bolted connection between load receiver and load cell ; e.g., model SWB220.



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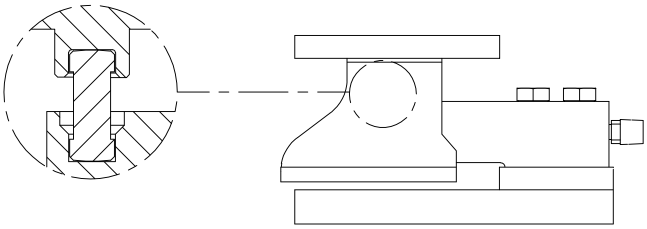
Sliding Suspension: A spherical washer set positioned against the load receiver (top plate), e.g., SWB 305. An additional bolt connects the top plate to the load cell through the spherical washer set and acts as anti-lift protection. This bolt is not part of the load introduction. VLM3 also has a sliding suspension where the load cell can slide laterally on hardened horizontal pins.



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Self-Aligning Suspension: Non-bolted connection consisting of a rocker load pin that is curved on both ends in contact with flat surfaces, or a ball and cup arrangement. This type of suspension provides the best weighing performance over the widest variety of applications. Weigh modules that use a rocker pin load cell are also self-aligning, e.g., Pinmount. *text removed

Which type of weigh module suspension should you use? Table 6-1 provides guidelines for proper application.

Type of Suspension	Application Parameters
Rigid	Static or dynamic loading without thermal expansion/contraction, piping connections, or high horizontal shear loads.
Sliding	Static loading with thermal expansion/contraction and flexible piping connections.
Self-Aligning	Static or dynamic loading with horizontal shear loads, thermal expansion/contraction, and flexible piping connections. Use when best weighing performance is required.

Table 6-1: Weigh Module Suspensions

Application Examples for Self-Aligning Weigh Modules

Self-Aligning Suspensions with Stabilizers

Self-aligning weigh modules offer the best weighing performance over the widest variety of applications. Some weigh modules with self-aligning suspensions can be equipped with optional stabilizers to prevent horizontal movement in one direction. The stabilizer consists of adjustable rod end bearings that connect the top mounting plate (load receiver) to the base mounting plate (see Figure 6-1).

Note: The stabilizer option is not intended to provide additional horizontal force capacity.

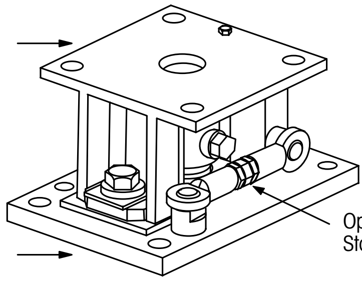


Figure 6-1: Self-Aligning Weigh Module with Stabilizer

There are three situations in which you would use stabilizers:

1. To stabilize a dynamic scale if weighing must take place while, for example, a large mixer is operating.
2. To stabilize a scale where settling time is critical, for example, a high-speed conveyor scale.
3. To stabilize a dynamic scale in order to protect rigidly attached piping from fatigue and failure.

We recommend using stabilizers for the following types of applications.

- **Tank with High-Shear Mixer:** A high-shear mixer has an outer stator held by the outer rods while a concentric rotor is driven by the central shaft. These devices disperse, emulsify, homogenize, disintegrate, and dissolve liquids or solids in liquids. Materials can be added in large chunks, creating a pulsating effect as they are drawn into the stator. These mixers are typically driven at high speeds and can create high levels of vibration and pulsation. If they operate during weighing, then stabilizers are recommended (see Figure 6-2).

- **Tank Scale with Mixer and Rigid Piping:** When a tank has a powerful mixer and rigid piping, the tank's constant oscillation can cause fatigue cracking of the pipework. Regardless of whether the mixer operates during weighing, stabilizers can be used to steady the tank and prevent damage to the piping. Note that rigid piping is not recommended because it substantially degrades weighing performance (see Figure 6-3).

- **Horizontal Batch Mixer:** This device has a motor driving a horizontal agitator shaft, which can be a screw or be equipped with paddles. The agitator shaft rotates in a horizontal trough and is typically used to mix or coat dry ingredients and to create slurries or pastes. Typical applications are mixing animal feeds, coating seeds, and mixing concrete. Electric motors up to 150 kW (200 hp) are used, and heavy vibration can be expected because of the nature of the operation. If the agitators operate during weighing, then stabilizers are recommended (see Figure 6-4).

- **High-Speed Conveyor Scale:** High-speed conveyor scales with heavy capacities are rare. If settling time is critical for this type of application, stabilizers should be used to steady the scale (see Figure 6-5).

- **Vehicle WIM Scale:** A Weigh-in-Motion (WIM) scale weighs each axle of a vehicle as the vehicle is driven slowly across the scale and then sums the values to calculate the total weight. This type of application usually involves a pit scale that is wider than the vehicle and long enough to accommodate single or tandem axles. Because settling time is critical, stabilizers should be used to steady the scale (see Figure 6-6).

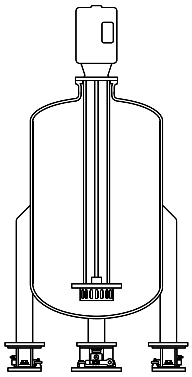


Figure 6-2: Tank Scale with High-Shear Mixer

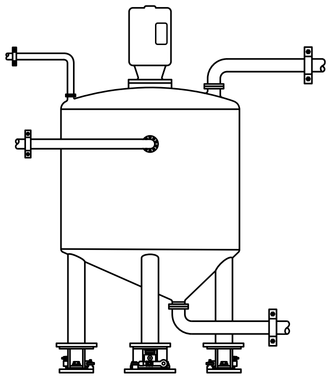


Figure 6-3: Tank Scale with Mixer and Rigid Piping

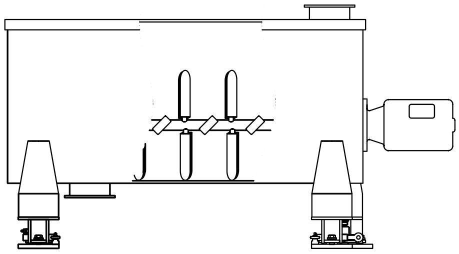


Figure 6-4: Horizontal Batch Mixer

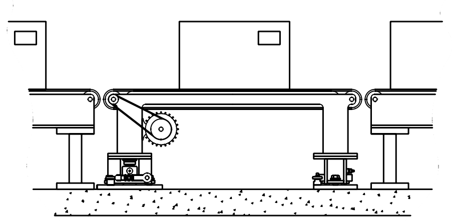


Figure 6-5: High-Speed Conveyor Scale

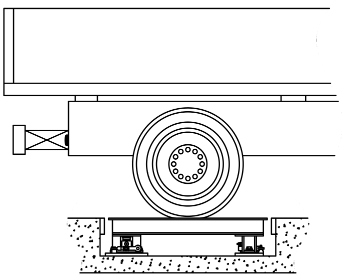


Figure 6-6: Vehicle Scale for Weighing in Motion

Self-Aligning Weigh Modules without Stabilizers

Stabilizers are not required for the following types of applications:

- **Tank Scale, Static:** A static tank scale, either horizontal or vertical, does not have mixers or violent chemical reactions that would cause the tank to move horizontally. The act of filling and emptying alone does not require stabilizers to be used. A static tank scale does not require stabilizers (see Figure 6-7).

- **Tank Scale, Stirred:** Some tanks have a low-powered mixer with a power rating of 1.5 kW (2 hp) or less. The liquid is stirred with a small marine-type impeller, typically not more than 150 mm (6 inches) in diameter. With suitable filtering software on the indicator, this application typically does not require stabilizers even if stirring occurs during weighing (see Figure 6-8).

- **Tank Scale with Mixer, Static Weighing:** This type of scale is subject to dynamic forces at times but not during the weighing operation. Because the mixer does not affect the weighing results, stabilizers are not required (see Figure 6-9).

- **Hopper Scale:** Some hopper scales have vibrators to aid emptying. Gates can cause additional impact forces when opening and closing. As long as the forces are not present during weighing, a hopper scale does not require stabilizers (see Figure 6-10).

- **Conveyor Scale, Low Speed:** For low-speed conveyor scale applications (often of high capacity) settling time is typically not critical. Instead of using stabilizers, it is better to let the scale float freely to absorb shocks and restore itself after any horizontal impacts (see Figure 6-11).

- **Platform Scale:** As long as a platform scale is not subjected to dynamic forces and settling time is not an issue, stabilizers are not required. Even if the platform scale is bumped occasionally (for example, while being loaded by a forklift), it is better to let it float freely to absorb shocks and restore itself after the impact (see Figure 6-12).

- **Platform Scale, Drive-On:** If a platform scale is used to weigh motorized vehicles such as forklifts, large horizontal forces can result when the vehicle stops. Typically, settling time is not critical in these applications. The normal configuration is to allow the scale to float freely (no stabilizers) but with external bumper bolts to restrict horizontal movement. The bumper gaps should be small enough so that the platform bumps against the external bumpers before contacting the weigh module's bumpers (see Figure 6-13). **Note:** Although stabilizers are not required for this type of dynamic scale, we recommend using external stops or checking.

- **Coil Scale, External Stop:** With this type of scale, the coil rolls down an incline onto the scale, is stopped by an externally mounted stop, and settles back into a "V" notch in the deck for weighing. After weighing, the stop is raised and the coil is ejected from the notch so that it can roll off the scale. Generally, settling time is not important. Instead of using stabilizers, it is better to let the scale float freely to absorb shocks and to restore itself after any horizontal impact (see Figure 6-14).

- **Coil Scale, Live Stop:** With this type of scale, the coil rolls down an incline onto the scale and is stopped and held in place by a stop mounted on the live scale. After weighing, the stop is retracted and the coil rolls off the scale. Generally, settling time is not important. Severe horizontal forces result when the coil hits the stop. Instead of using stabilizers, it is better to let the scale float freely until it hits external bumpers. The face of the retractable stop should be lined with a compliant (spring-type) material. The bumper gap should be small enough so that the platform bumps against the external bumpers before contacting the weigh module's bumpers (see Figure 6-15). **Note:** Although stabilizers are not required for this type of dynamic scale, we recommend using external stops or checking.

Note: Sometimes a mixer is mounted independently of the scale on a structural member or on a stand that sits on the floor (see Figure 6-16). It is important to remember that the impeller's thrust will cause the scale to seem much lighter or heavier depending on the direction of rotation. It is important that weighing not take place when this type of mixer is operating.

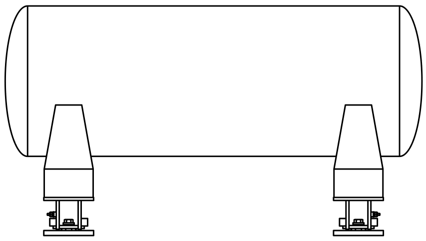


Figure 6-7: Tank Scale, Static

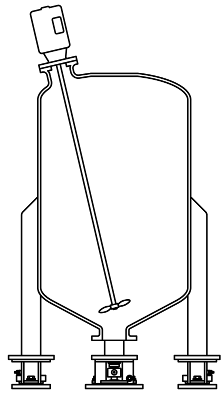


Figure 6-8: Tank Scale, Stirred

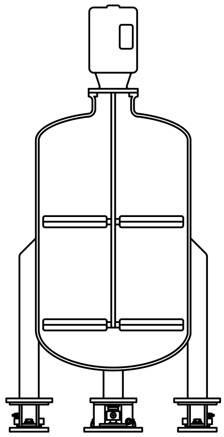


Figure 6-9: Tank Scale with Mixer, Static Weighing

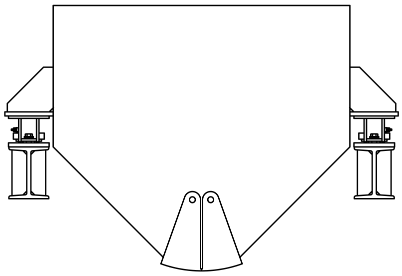


Figure 6-10: Hopper Scale

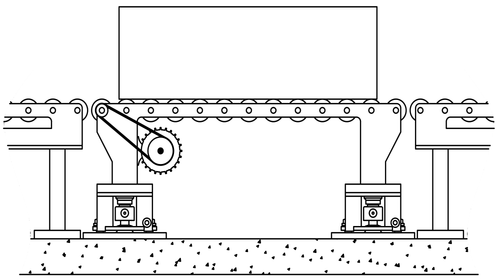


Figure 6-11: Conveyor Scale, Low Speed

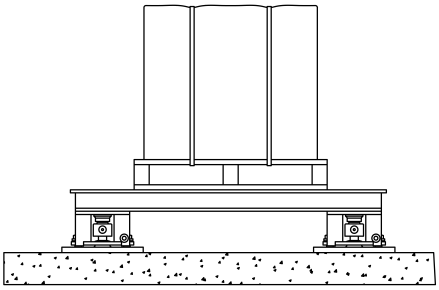


Figure 6-12: Platform Scale

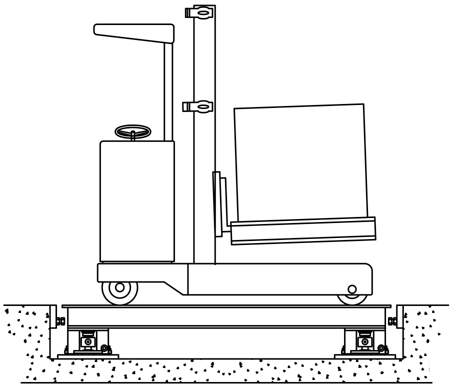


Figure 6-13: Platform Scale, Drive-On

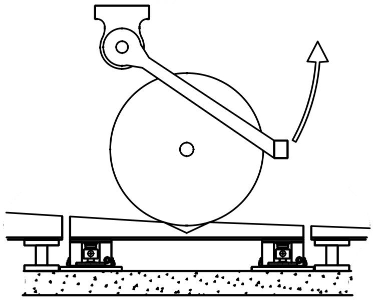


Figure 6-14: Coil Scale, External Stop

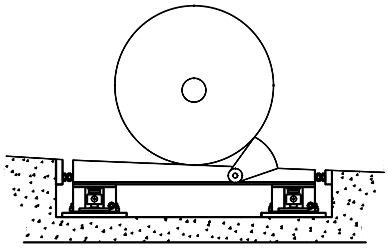


Figure 6-15: Platform Scale, Drive-On

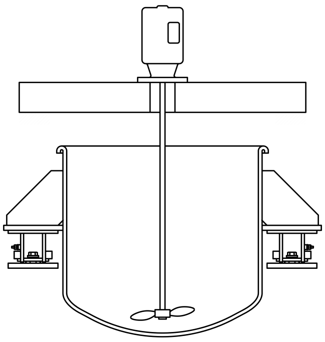


Figure 6-16: Mixer Mounted Independently

Sizing Weigh Modules, Even Load Distribution

To design a tank scale that will weigh its contents accurately and will not be damaged in operation, you must use weigh modules with the proper load cell capacity. This section deals with scales where load distribution is approximately even across all weigh modules; this would be typical of symmetrically shaped tanks, hoppers and reactor vessels with symmetrical placement of the weigh modules. In this case there are three main factors in sizing weigh modules for a scale: (1) the weight of the empty scale, (2) the weight of the scale's contents when full, and (3) the number of weigh modules. The number of weigh modules will equal the number of legs or supports that the scale has.

A standard safety factor of 1.25 is normally figured into the calculation to compensate for some uneven load distribution and any underestimation of weights. Certain installations might have special environmental considerations requiring additional safety factors, and these are discussed in Chapter 4, Weigh Module Environmental Factors.

Calculating Weigh Module Size

Suppose that you want to add weigh modules to a tank designed to hold 20,000 lb [10,000 kg] of a liquid. The tank itself weighs 10,000 lb [5,000 kg] and stands on four legs. Assume that only the standard safety factor is needed for this installation. To determine what size weigh modules you will need, calculate the total weight of the tank and its contents, figure in any safety factors, and then divide by the number of weigh modules.

Imperial		Metric
20,000 lb	Weight of liquid	10,000 kg
+ 10,000 lb	Weight of empty tank	+ 5,000 kg
30,000 lb	Total weight	15,000 kg
× 1.25	Safety factor	× 1.25
37,500 lb	Adjusted weight	18,750 kg
÷ 4	Number of weigh modules	÷ 4
9,375 lb	Weight per weigh module	4,688 kg

Since each weigh module will need to handle up to 9,375 lb [4,688 kg], the best choice for the job would be weigh modules with a capacity of 10,000 lb [5,000 kg] each. See the following section for a discussion of scales with uneven load distribution.

In selecting load cell capacity consider also abnormal use or abuse of the scale, here are some examples:

- It is very common for low capacity in-pit floor scales to be damaged by forklifts or other vehicles driving across it.
- While airport baggage check-in scales may not need to weigh in excess of 100 lb [45 kg] it is common to see them being walked-across.
- Bench scales have been known to be damaged by people changing light bulbs.
- If a fill valve sticks open on a tank scale it can fill beyond the intended capacity.

It may be possible to select load cells that will not be damaged regardless, but accuracy is the trade-off. In such situations consider guard-rails, overload devices, warning signs, employee training, etc.

Sizing Weigh Modules, Uneven Load Distribution

To design a scale that will weigh material accurately and will not be damaged in operation, you must use weigh modules with the proper load cell capacity. This section deals with scales where load distribution can vary widely, scales such as platform, coil and conveyor scales where concentrated loads can be placed eccentrically or that roll across the scale. For example, when a loaded forklift drives onto a platform scale the entire load essentially can be carried by the front wheels thus applying all the load momentarily to just two weigh modules. In these cases there are four main factors in sizing the weigh modules: (1) the empty weight of the weighbridge on which the material will be placed, (2) the maximum weight of the material or object to be weighed, (3) the number of weigh modules, and (4) the type of loading. The most common type of loading in this category is full end loading of a platform scale, but uneven load distribution can occur with non-symmetrical scales and/or weigh module placement, eccentrically mounted machinery on tank scales or conveyors, to mention just a few.

To better understand the difference between full end loading and distributed loading, imagine a conveyor scale with a weigh module in each of its four corners. Full end loading can occur when a small dense object moves across a relatively long conveyor. Initially the object's full weight will be concentrated on the two weigh modules at the inbound side of the scale. Only when the object approaches the center of the conveyor will its weight be distributed evenly across all four weigh modules. Distributed loading occurs when an object with a large footprint moves across a relatively small conveyor scale. By the time its full weight is on the scale, part of the load has been transferred to the weigh modules at the outbound side of the scale. If full end loading is a requirement then you will need to size the weigh modules so that two of them are capable of supporting the full load.

A standard safety factor of 1.25 is normally figured into the calculation to cover unforeseen circumstances, underestimation of weights, etc. Certain installations might have special environmental considerations requiring additional safety factors; refer to Chapter 4, Weigh Module Environmental Factors.

Calculating Weigh Module Size

Suppose that you want to size weigh modules for a coil scale with a square platform designed to weigh a 3,000 lb [1’500 kg] coil of steel. The coil scale itself weighs 2,000 lb [1’000 kg] and is to be supported by four weigh modules. Since the coil will roll onto the scale from one end, the system must be sized for full end loading over two weigh modules. In this case calculate the total weight to be applied to 2 weigh modules (the weight of the coil + half the dead weight of the scale), figure in any safety factors, and then divide by two, the number of weigh modules sharing that load.

Imperial		Metric
3,000 lb	Weight of coil	1,500 kg
+ 1,000 lb	Weight of empty scale ÷ 2	+ 500 kg
4,000 lb	Total weight	2,000 kg
× 1.25	Safety factor	× 1.25
5,000 lb	Adjusted weight	2,500 kg
÷ 2	Number of weigh modules	÷ 2
2,500 lb	Weight per weigh module	1,250 kg

Use four 2,500lb [1,250 kg] self-aligning weigh modules for this application. If that capacity is not available, use the next available larger size.

Where the uneven load distribution is due to a non-symmetrical scale, non-symmetrical weigh module placement, eccentrically mounted machinery, etc, individual calculations will need to be performed to ensure that the weigh module rated capacity is never exceeded.

Anti-Lift Considerations

Wind, seismic, or accidental forces can be strong enough to tip over some tanks. If there is a potential for your tank to tip over, consider using weigh modules with built-in anti-lift devices. Otherwise, external checking will be required to resist tipping moments.

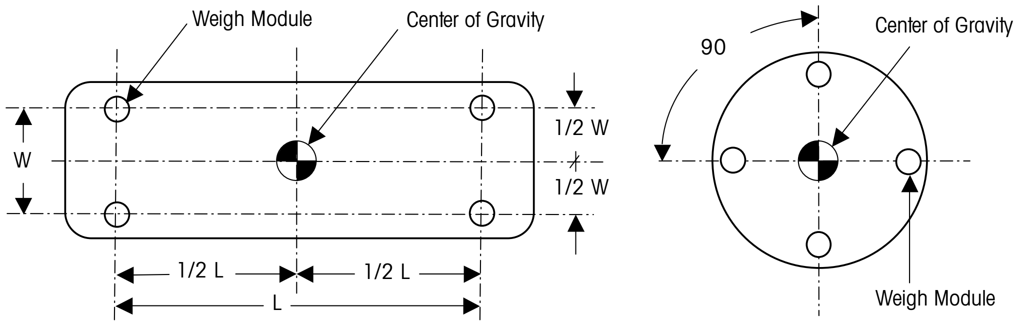
Selecting Material

Load cells and other weigh module components can be manufactured of carbon steel or stainless steel. Weigh modules that will be exposed to wet or corrosive environments are generally made of stainless steel. When selecting weigh modules, you will need to consider the environment in which they will be used and the materials that your facility will handle. Refer to Chapter 10, appendix 6, Chemical Resistance Chart, which provides chemical resistance data to aid in selecting materials.

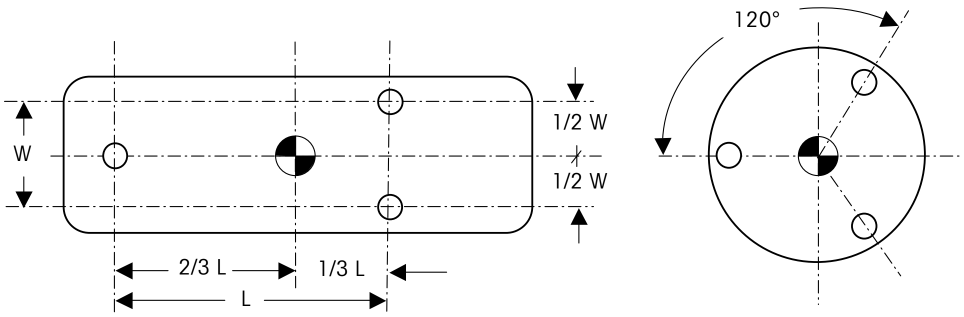
Weigh Module Orientation

Before installing the weigh modules, decide how they will be arranged on your tank. Space the weigh modules so they support approximately equal amounts of weight, and make sure that the weigh modules are properly oriented to one another. How the weigh module is oriented depends on its design. Orientation can also be affected by options such as stabilizers; in that case we recommend that the weigh modules be oriented as if they have stabilizers so this option can be added in the future if required. For proper orientation guidelines, refer to the Installation and Service Manual for the weigh modules that are being installed.

Typical layouts for systems using three or four weigh modules are shown in Figure 6-17.



Plan View: Rectangular / Square and Circular 4-module Layouts



Plan View: Rectangular / Square and Circular 3-module Layouts

Figure 6-17: Typical Layouts for Systems Using Three or Four Weigh Modules

Level Detection Systems

If a relatively inaccurate level detection system is sufficient, with accuracy of 0.5% to 2% of system capacity, then you can reduce costs by using a system that combines "live" and "dead" weigh modules. This type of system is often used in applications such as bulk-storage tanks or silos where it is sufficient to have just a rough indication of the content in order, for example, not to run empty. Each "live" weigh module uses a functioning load cell, while each "dead" weigh module uses a nonfunctioning dummy load cell or consists of a simple welded dead stand with the same mounting geometry as the weigh modules.

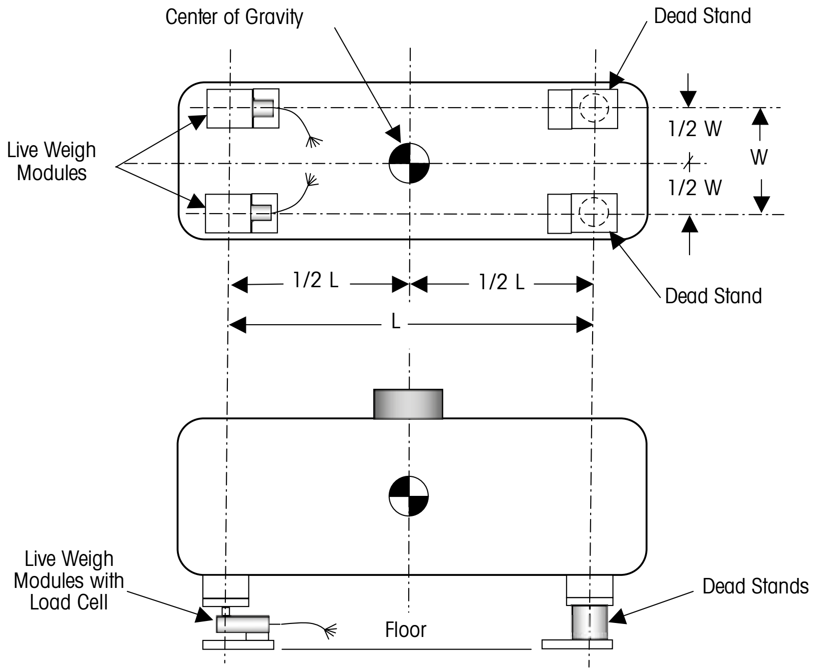
Although a welded dead stand is less expensive, a weigh module with a dummy load cell gives you the option of adding a live, functioning load cell at a later date if system accuracy is not adequate. If you use a welded dead stand, make sure it has load ratings equal to or greater than the corresponding live weigh module.

Level detection systems are most suited to tank scales weighing liquids or gases. They are less well suited to weighing self-leveling solids as variation in the location of the center of gravity in a horizontal plane will cause inaccuracies. Mettler-Toledo does not recommend the use of level detection systems for use with non self-leveling powders or granular materials; they cannot be used with platform scales weighing concentrated loads as such loads cannot be positioned repeatably. The tank or silo must also be symmetrical about a vertical axis along which the center of gravity (C.G.) rises/falls as the tank or silo is filled/emptied. This ensures that a consistent percentage of the load is applied to each support point, live or dead. Consistent load distribution is critical to the performance of a level detection system.

We recommend using level detection systems on tanks requiring three or four support points only. A tank with three support points uses one live module and two dead modules or dead stands. A tank with four support points must use two live modules and two dead modules or dead stands.

Figure 6-18 shows the optimum positioning of live weigh modules for a square or rectangular four-module level detection system. In this case it can be assumed that the live weigh modules carry 50% of the applied load and calibration may be performed by electronic simulation or using CalFree. Note that the live weigh modules must not be placed across the diagonal from each other.

It is not required that the support points be arranged to all carry the same load, but if not then calibration should be performed using weight.



Plan & Elevation View: Four-module Level Detection System (two live and two dead modules)

Figure 6-18: Layout for a Four-Module Level Detection System

In sizing the live weigh module(s), use the procedure in "Sizing Weigh Modules, Even Load Distribution" above using the total number of support points in place of the number of weigh modules.

Installation

For detailed installation instructions refer to the weigh module's Installation and Service Manual. The actual installation procedure will depend on the specific requirements of an application. One of the first things to consider is the foundation on which the tank scale will be placed. This is usually a concrete floor or steel support structure. Whichever you are using, you will need to make sure that it is strong enough to remain rigid under the weight of the full tank scale. Base plate bearing data (the pressure that a weigh module exerts on a foundation) is usually listed in the weigh module installation and service manual.

NOTE: Make sure to design the tank and support structure so that the load cells will be easy to service. With many types of weigh modules, the top plate must be lifted in order to remove a load cell. If a tank has many piping connections, lifting a top plate can lead to extra expense and downtime. Installing optional spacer plates (available from METTLER TOLEDO) between the weigh modules and tank allow you to service the load cells simply by removing load from the weigh module.

General Procedure
Protect the load cells during installation, make sure that the weigh modules are in the installation mode.

1. Position a weigh module under each of the tank's support legs or mounting bracket, and slowly lower the tank onto the weigh modules.
2. Make sure that each load point on the tank is well supported by a weigh module's top plate and that all top plates are level within ± 1/2 degree, see note at end of this section. Otherwise, add shims until each load point is supported and the top plates are level.
3. Where lift-off forces are expected, make sure that the top and base plate anchoring method is able to carry the load. If welding this refers to the weld length and size; if bolting it refers to the size and strength grade of the bolts or J-bolts; if you use expansion anchors or epoxy inserts make sure they are suitable based on their specification and installed according to the manufacturer's recommendations.

Shimming Notes:
Top Plates
- Use full-size shims (equal to the top plate dimensions) to redistribute weight or eliminate rocking across corners of the tank.
- Use partial-plate shims or stainless steel shim kits to fill voids between the top plate and tank leg / mounting bracket. In particular support the center point of the top plate where the support forces are concentrated.

*text deleted

Base Plates
- Use an injectable grout (such as Hilti HIT HY 150) to fill large voids between the base plate and concrete foundation.
- Base plates may be shimmed with metal shims as described above, paying special attention to supporting the point of load application to the top of the plate, usually its center point.

⚠ CAUTION

DO NOT CALIBRATE WITH WEIGHT OR LOAD THE SCALE UNTIL THE SHIMMING IS COMPLETE, OTHERWISE THE WEIGH MODULES MAY BE DAMAGED.

Bolt or weld the top plate of each weigh module to the support leg or mounting lug that is resting on it according to specific instructions.

Note that certain weigh modules, for example SWB220, SWB305 and SWB805, must not be welded in place because of the danger of damaging seals or elastomeric elements; further you will need to remove these top plates if a load cell needs to be replaced.

⚠ CAUTION

DO NOT PASS WELDING CURRENT THROUGH THE LOAD CELLS! WHEN WELDING ON A SCALE, ALWAYS GROUND THE WELDING DEVICE AS CLOSE TO THE WORK AS POSSIBLE. NEVER WELD CLOSER THAN 4 FEET (1.2 METERS) TO ANY LOAD CELL WITHOUT REMOVING THE LOAD CELL.

4. Lower the tank onto the support foundation (concrete slab or support beam). Mark the position of the base plate mounting holes on the foundation (see Figure 6-19).

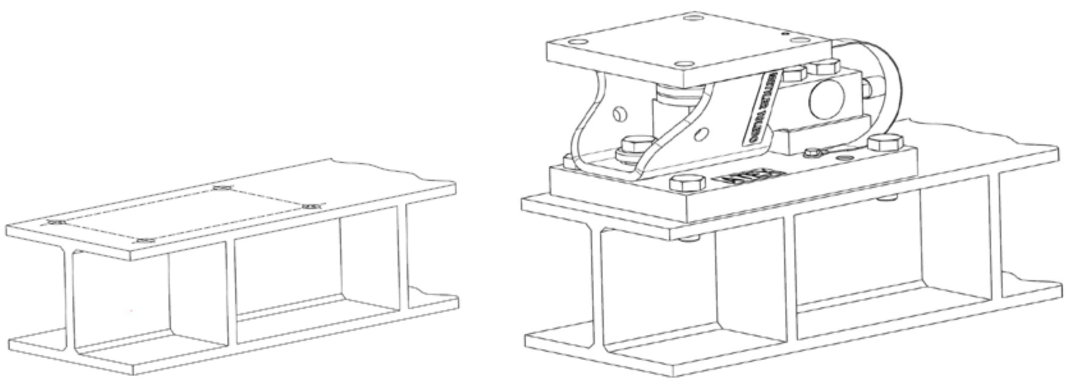


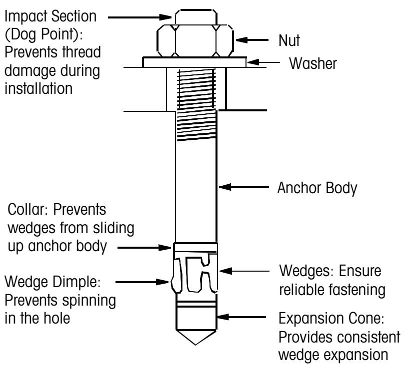
Figure 6-19: Locating Bolt Holes in Support Steel

5. Raise the tank out of the way if necessary and drill the appropriate size anchoring holes in the support foundation.

6. Anchor the weigh module base plates to the foundation, using the instructions given below for the appropriate type of foundation. Level each base plate to within ±1/2 degree, see note at end of this section. All base plates must be in the same level plane within ± 1/8 inch [± 3mm].

For a Level Concrete Floor Foundation:

Lower the tank back onto the foundation so that the base plate mounting holes line up with the holes that were drilled in the concrete. Insert a wedge-design expansion anchor bolt into each base plate mounting hole (see Figure 6-20). Follow the anchor bolt manufacturer's instructions regarding the size and depth of holes and recommended torque values.



Expansion Anchor Bolt Detail

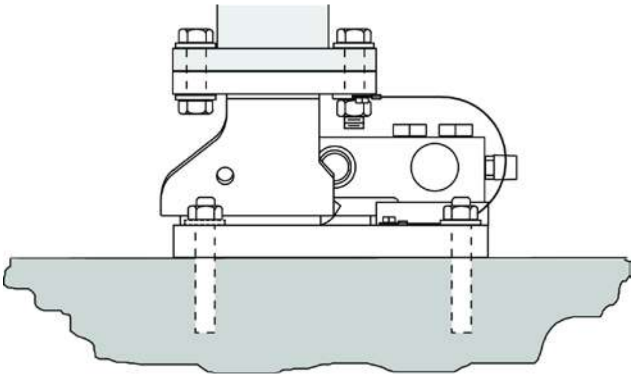


Figure 6-20: Base Plate Bolted to Level Concrete Floor

For an Unlevel Concrete Floor Foundation:

The bolts used to fasten the base plate can also be used during installation to support and level the base plates. Install threaded epoxy inserts into existing concrete or cast J-bolts into the foundation when the concrete is being poured. Place leveling nuts and washers beneath the base plates to adjust for level. Keep the space between each base plate and the concrete floor to a minimum, and fill it with a nonshrink, epoxy grout once all base plates are level to ± ½ degree and in the same plane to within ± 1/8 inch [± 3mm] (see Figure 6-21).

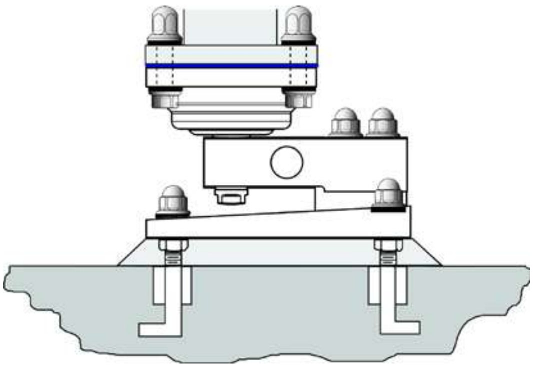


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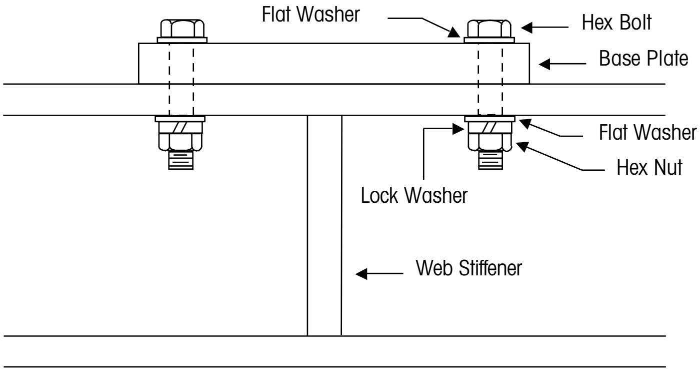
Figure 6-21: Base Plate Bolted to Unlevel Concrete Floor

Note: If you use J-bolt anchors, you will need to place them in the concrete accurately before pouring; for example, use a wooden template to locate and hold them in position while the concrete is poured.

For a Structural Beam Foundation:
Use through bolts, washers, and nuts to anchor the base plate to the flange of the structural beam (see Figure 6-22). Install web stiffeners to prevent the beam from twisting. If shimming is required to level the base plates or to keep them in the same plane, add the shim beneath the entire base plate. If you are welding the base plates to the beam, do so in accordance with the Installation and Service Manual.



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For Centerlign weigh modules, replac...

Figure 6-22: Base Plate Bolted to Structural Beam

7. After securing all the top plates and base plates, carefully lower the top plate and weigh structure onto the load cells, as appropriate.

   - For weigh modules with hold-down bolts, make sure they are adjusted correctly and that there is adequate clearance between the hold-down bolts and retaining hole.
   - Insert the load cell if it was removed for installation.

   - Place the weigh module into the weighing mode in accordance with the Installation and Service Manual, if necessary.
   - Check that the load is distributed correctly on all weigh modules, fine tune by adjusting the shimming if necessary.

8. Mount the junction box in a location where the load cell cables can be properly terminated in the junction box. Choose a location where it will be protected from splashes and washdown, if applicable. Do not mount the junction box on the scale as this requires the cables to cross from the dead foundation to the live scale and may affect accuracy. Do not mount the junction box to a heated surface, for example, the side of the tank where a heating jacket is present.

   Note: Each load cell is supplied with a standard length of cable. Do not lengthen or shorten load cell cables in the field! Changing the length of a load cell cable will affect the output signal from the load cell. If a cable is too long, simply coil the excess cable and place it in or near the junction box. Nonstandard lengths of cable can be ordered for applications that require them.

9. Connect the load cell cables to the junction box and terminate the wires according to the color code supplied with the load cell and the junction box instructions.

10. Connect the home run cable from the scale indicator to the junction box.

11. Confirm that all live-to-dead connections (such as piping) are flexible and securely anchored at both the scale and dead connection point.

12. Calibrate the scale.

Note:
We specify that top and base plates be level within ± ½ degree of the horizontal. This is equivalent to a 1/32 inch rise or fall for every 4 inches of run. For example, if a base plate was 8 inches long, it could rise or fall by (8/4) × 1/32 = 1/16 in maximum over its length.

In metric units ± ½ degree is equivalent to 1mm rise or fall for every 125mm of run. For example, if a base plate was 250mm long, it could rise or fall by (250/125) × 1 = 2mm maximum over its length.

7. Tension Weigh Modules

Introduction

This chapter provides general information about how to install tension weigh modules. Each application has its own unique requirements and should be planned by a qualified structural engineer. When installing weigh modules, refer to the installation and service manual for the specific model.

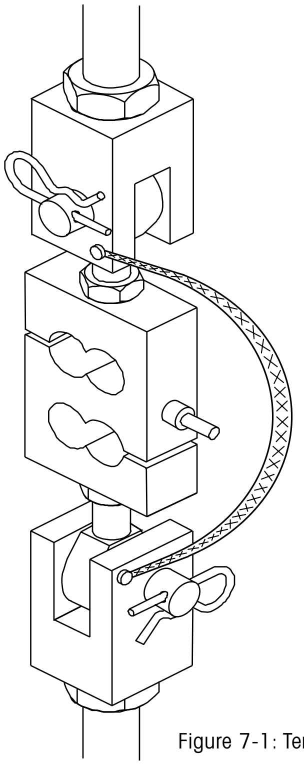


Figure 7-1: Tension Weigh Module

Sizing Weigh Modules

To design a hopper scale that will weigh its contents accurately and will not be damaged in operation, you must use weigh modules with the proper load cell capacity. There are three main factors in sizing weigh modules for a hopper scale: (1) the weight of the empty hopper, (2) the weight of the hopper's contents when full, and (3) the number of weigh modules. The number of weigh modules will equal the number of supports that the hopper has.

A standard safety factor of 1.25 is normally figured into the calculation to compensate for some uneven load distribution and any underestimation of weights. Certain installations have special environmental considerations requiring additional safety factors and these are discussed in Chapter 4, Weigh Module Environmental Considerations.

Calculating Weigh Module Size

Suppose that you want to add weigh modules to a hopper designed to hold 20,000 lb [10,000 kg] of grain. The hopper itself weighs 5,000 lb [2,500 kg] and is supported by four threaded rods. Assume that only the standard safety factor is needed for this installation. To determine what size weigh modules you will need, calculate the total weight of the hopper and its contents, figure in any safety factors, and then divide by the number of weigh modules.

Imperial		**Metric**
20,000 lb	Weight of grain	10,000 kg
+ 5,000 lb	Weight of empty hopper	+ 2,500 kg
25,000 lb	Total weight	12,500 kg
× 1.25	Safety factor	× 1.25
31,250 lb	Adjusted weight	15,625 kg
÷ 4	Number of weigh modules	÷ 4
7,813 lb	Weight per weigh module	3,906 kg

Since each weigh module will need to handle up to 7,813 lb [3,906 kg], the best choice for the job would be tension weigh modules with a capacity of 10,000 lb [5,000 kg] each. This section assumes relatively even load distribution which is generally the case for tension applications; if load distribution is uneven, refer to Sizing Weigh Modules, Uneven Load Distribution in Chapter 6, Compression Weigh Modules.

⚠ WARNING

ALWAYS INSTALL A SECONDARY SAFETY SUPPORT SYSTEM (CHAINS, RODS, ETC.) TO PREVENT THE SUSPENDED TANK/HOPPER FROM FALLING IN CASE OF TENSION LINKAGE OR WEIGH MODULE COMPONENT FAILURE.

Installation

For detailed installation instructions refer to the weigh module's Installation and Service Manual.
To maintain the system's weighing accuracy, make sure that the support steel will not deflect excessively under full working load.

General Procedure

1. Position the tension weigh modules around the tank so that each will support an equal portion of the tank's weight approximately (see Figure 7-2). Make sure that the support brackets overhead on the structure and those on the scale are aligned properly; better still, make some adjustable for fine tuning during installation.

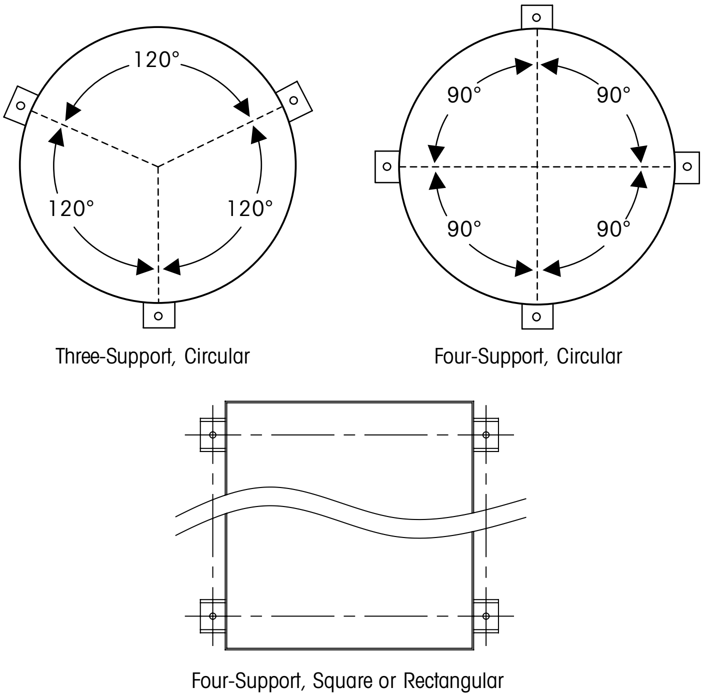


Figure 7-2: Plan View of Recommended Weigh Module Arrangements

2. Mettler-Toledo's tension weigh modules use S-beam type load cells. All S-beam load cells must be oriented correctly. The two possible orientations are illustrated in Figures 7-3a and 7-3b; here the cover plates have been removed to expose the horizontal beams. As illustrated their upper end is fixed; when load is applied to the lower end the beams deflect causing the live side and lower end to move downwards. It is important that the cable exits from the dead side of the load cell as shown in Figure 7-3b; otherwise the cable is a live-to-dead bridge and inaccuracies can result, especially with low capacities. If necessary change the orientation of an S-beam load cell by rotating it 180 degrees about a horizontal axis.

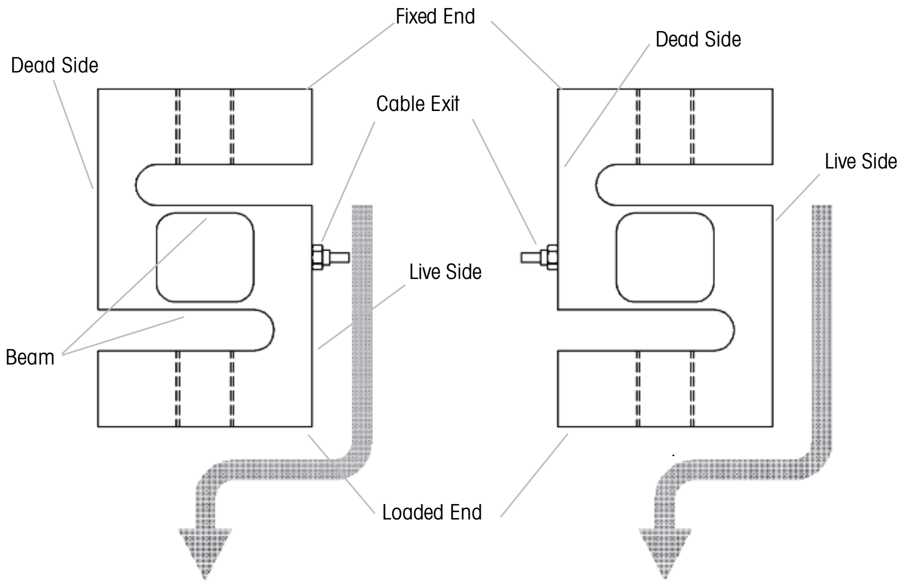


Figure 7-3a: Incorrect S-beam Orientation

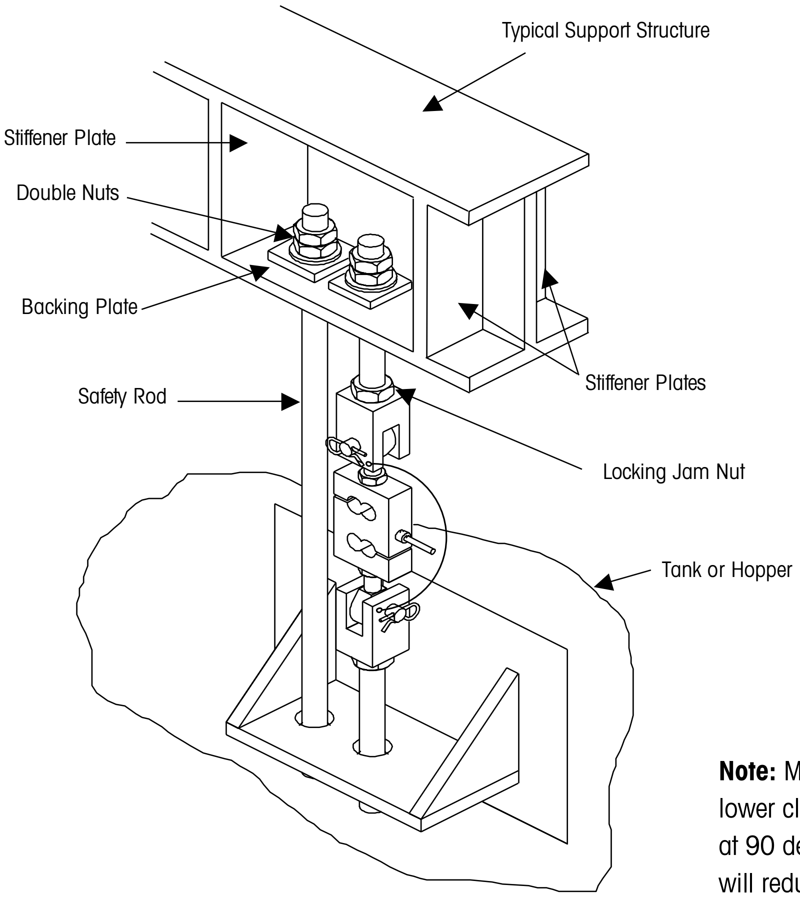
Figure 7-3b: Correct S-beam Orientation

3. Use threaded rod of the correct size and strength to safely support the hopper. Connect each weigh module clevis to the threaded rod with a jam nut on it. Screw the threaded rod in until all threads in the clevis are engaged. Tighten the jam nut against the clevis to prevent the threaded rod from turning.

⚠ WARNING

ALWAYS INSTALL A SECONDARY SAFETY SUPPORT SYSTEM (CHAINS, RODS, ETC.) TO PREVENT THE SUSPENDED TANK/HOPPER FROM FALLING IN CASE OF TENSION LINKAGE OR WEIGH MODULE COMPONENT FAILURE.

4. Place the threaded rod through a hole in the upper support bracket; make sure that the load cell is oriented correctly as discussed in 2. above. Fit a backing plate and washer over the end of the threaded rod. Then double-nut the threaded rod against the backing plate. Attach the other end of the weigh module assembly in the same way (see Figure 7-4). The weigh modules may be rotated about their vertical axis to any angle that suits the installation.



Note: Make sure that the upper and lower clevis brackets are turned at 90 degrees to each other. This will reduce swaying.

Figure 7-4: Typical Tension Weigh Module Installation

5. Install a safety backup next to each weigh module, a safety rod is illustrated here. Leave clearance between the lower support bracket and the washer on the safety rod (see Figure 7-5).

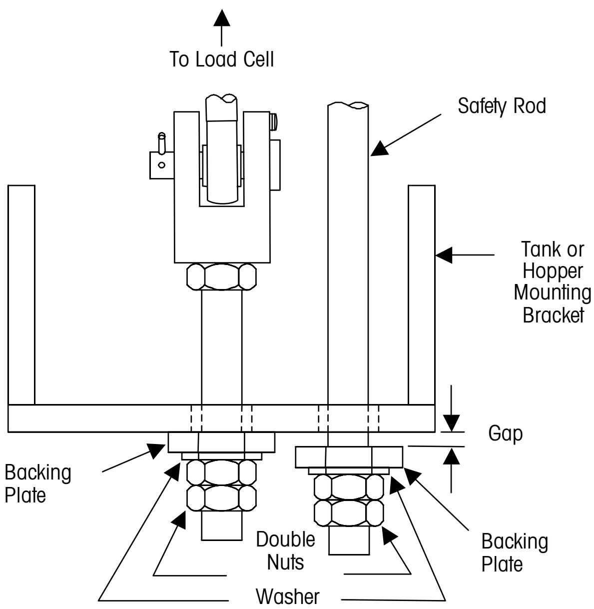


Figure 7-5: Weigh Module Assembly Attached to Lower Support Bracket

6. Once all weigh modules have been installed, make sure that each is hanging vertically (plumb). Adjust the length of the rods to achieve good load distribution.

7. Tack weld the backing plates into position. Pin or stake the nuts at both ends of the threaded rods to prevent them from turning. Check again the tightness of all jam nuts securing the threaded rods to the clevises.

8. If the suspended tank is subject to horizontal movement, install check rods or bumper bolts to limit horizontal movement. Figures 7-6 and 7-7 show typical arrangements. Note these are intended to limit gross movements of the scale, they are not intended to stabilize vibrating scales. Figures 7-8, 7-9, and 7-10 show typical tension weigh module installations.

9. Mount the junction box in a location where the load cell cables can be properly terminated in the junction box. Choose a location where it will be protected from splashes and washdown, if applicable. Do not mount the junction box on the scale as this requires the cables to cross from the dead foundation to the live scale and may affect accuracy. Do not mount the junction box to a heated surface, for example, the side of the tank where a heating jacket is present.

   Note: Each load cell is supplied with a standard length of cable. Do not lengthen or shorten load cell cables in the field! Changing the length of a load cell cable will affect the output and temperature compensation of the load cell. If a cable is too long, simply coil the excess cable and place it in or near the junction box.

10. Connect the load cell cables to the junction box and terminate the wires according to the color code supplied with the load cell and the junction box instructions.

11. Connect the junction box to the scale indicator with an appropriate cable.

12. Confirm that all live-to-dead connections are flexible and securely anchored at both the scale and the dead connection point.

13. Calibrate the scale.

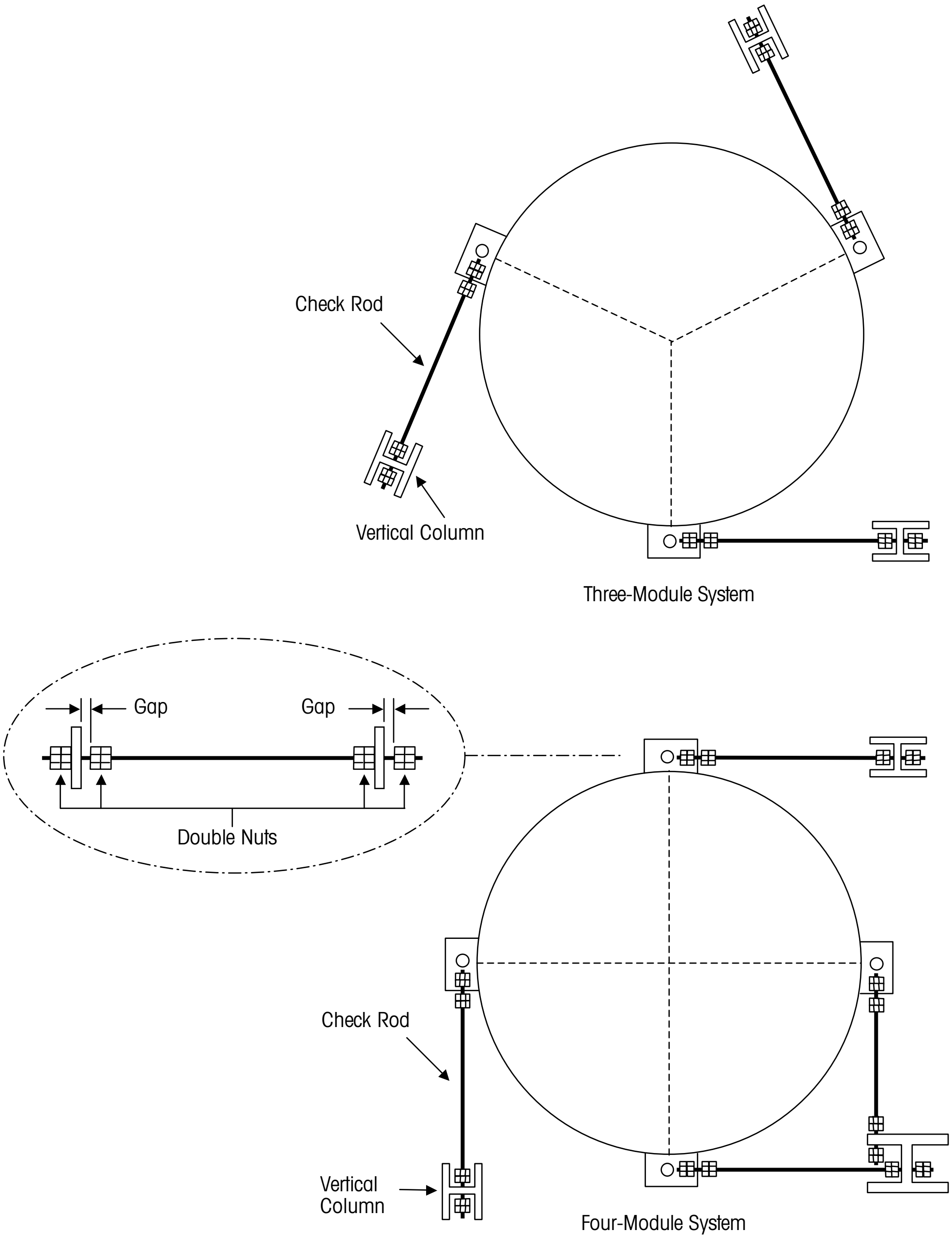


Figure 7-6: Plan View of Check Rods for Systems with Three and Four Weigh Modules

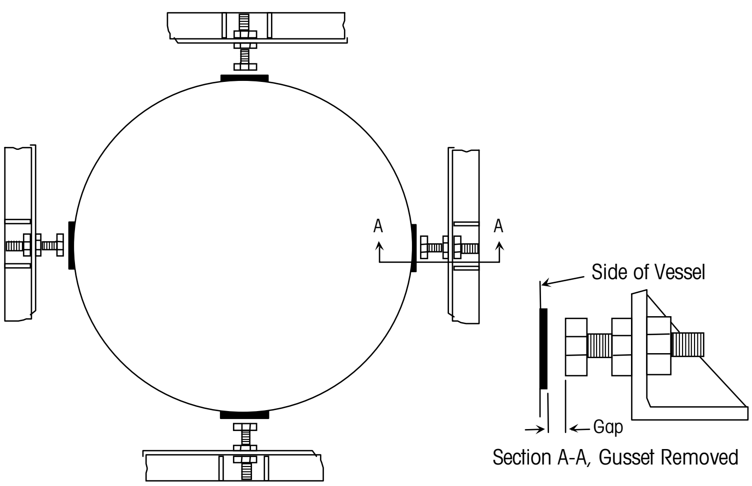


Figure 7-7: Plan View of Alternative bumper bolt System

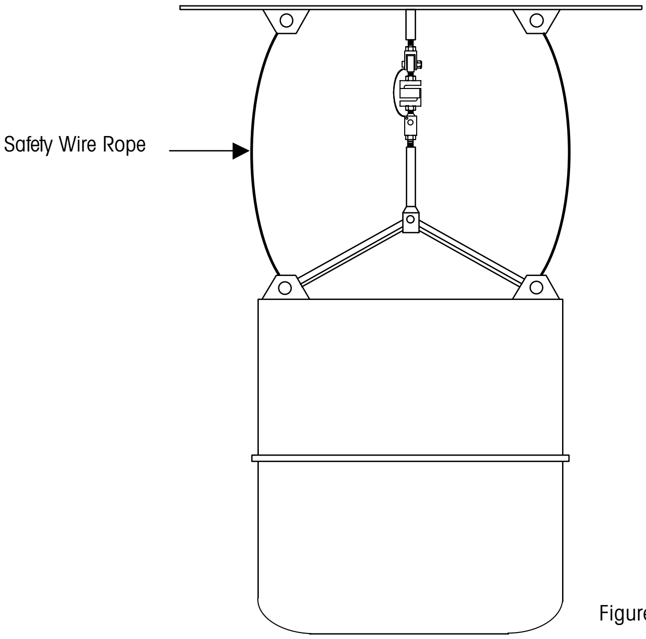


Figure 7-8: Sample Tension Weigh Module Installation

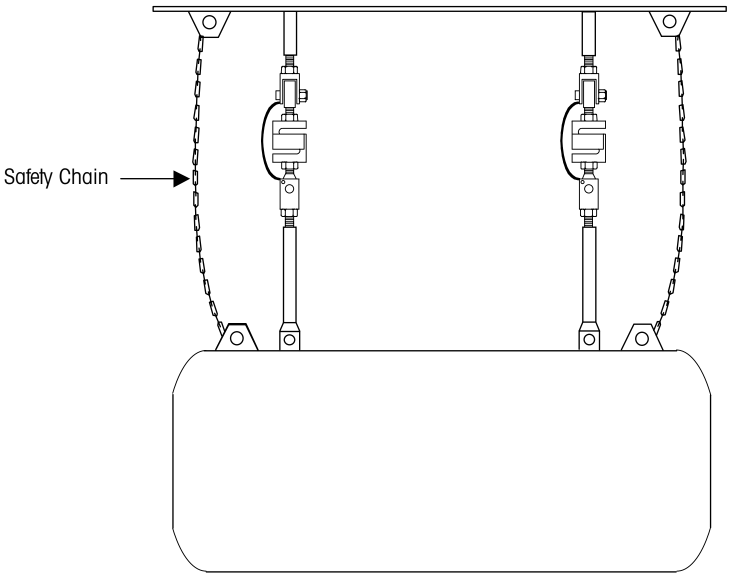


Figure 7-9: Sample Tension Weigh Module Installation

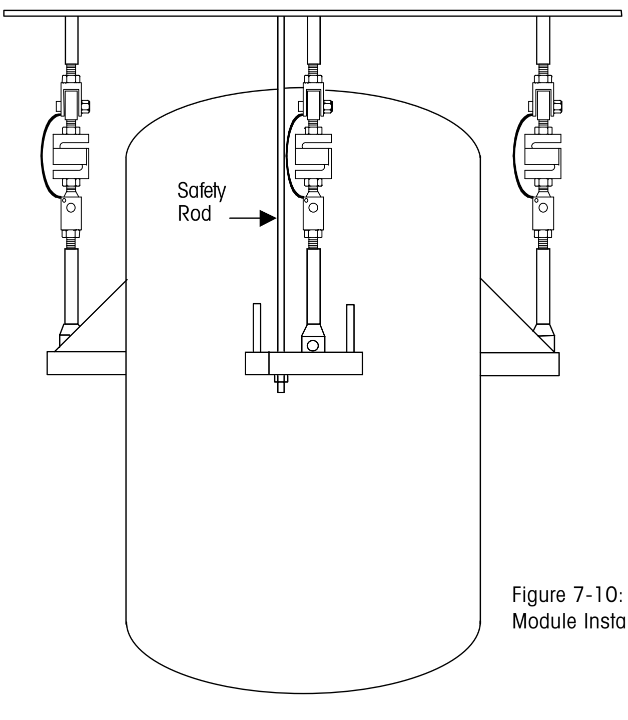


Figure 7-10: Sample Tension Weigh Module Installation

8. Weigh Module System Calibration

When a weigh module system is installed, it must be calibrated so that the readings on the indicator accurately reflect the amount of weight placed on the scale. METTLER TOLEDO recommends calibrating a scale using test weights equal to the scale's full capacity. Specific instructions for calibration can be found in the technical manual for the digital indicator that will be used with the weigh modules.

The design or size of a tank scale might make it impossible to hang test weights equal to the scale's full capacity. For those applications, there are several other calibration options: calibration with test weights and material substitution, calibration with material transfer, and electronic calibration.

⚠ **WARNING**

PERMIT ONLY QUALIFIED PERSONNEL TO SERVICE THIS EQUIPMENT. EXERCISE CARE WHEN MAKING CHECKS, TESTS, AND ADJUSTMENTS THAT MUST BE MADE WITH POWER ON. FAILING TO OBSERVE THESE PRECAUTIONS CAN RESULT IN BODILY HARM.

Calibration with Test Weights

The most accurate, reliable way to calibrate a scale is with test weights. For this calibration procedure, a tank scale needs to be equipped with some type of mounting lugs for hanging test weights (see Figure 5-7).

1. Begin by taking a weight reading for the empty tank. Adjust the indicator so that it reads zero when the tank is empty.
2. Check each load cell to make sure it is working properly. Hang a test weight near one weigh module and take a reading. Move the test weight to a second weigh module and take a reading. Repeat for each weigh module to make sure that all load cells indicate the same weight.
3. Check for repeatability to make sure there are no mechanical binding or support issues.
4. Add test weights to the scale, taking a reading for each new weight that is added up to the full capacity of the scale. At the very least, you should take weight readings at one quarter of capacity, one half of capacity, three quarters of capacity, and full capacity.
5. If the tank scale will be used to weigh its contents as they are being discharged, you should also take weight readings as you remove the test weights.
6. Use the readings to plot a graph of the scale's performance from zero to full capacity (and from full capacity back to zero if those readings were taken).

Calibration with Test Weights and Material Substitution

For large tank scales, it is often physically impossible to hang test weights equal to the tank's full capacity. In those cases, you can use a combination of test weights and a material (such as water) to calibrate the scale.

1. For example, after taking a zero reading you might hang 500 lb [225 kg] of test weights and take a reading.
2. Then remove the test weights and add water to the tank until the weight reading is the same as that obtained with the test weights.
3. With the water still in the tank, hang the same test weights and take a second reading.
4. Continue substituting water for the test weights and taking readings until you reach the tank's full capacity.
5. Once you have taken readings from zero to full capacity, use them to plot a graph of the scale's performance.

Calibration with Material Transfer

When test weights cannot be used, you can calibrate a scale with material transfer. Instead of hanging test weights, weigh a material (such as water) on another scale and transfer it to the tank scale that is being calibrated.
You can do this in a single transfer or in stages until you reach the tank's full capacity. This method yields only a rough indication of the scale's performance. It depends on the accuracy of the existing scale and the integrity of the transfer process. Even in the best conditions, you will not know if allowable errors are cumulative or compensating.

Calibration with Hydraulic Equipment

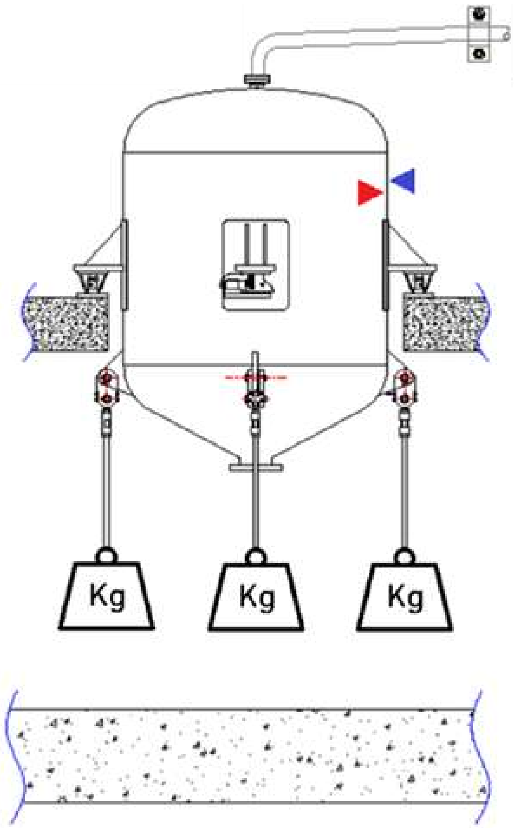
For larger tank scales, typically above 1 or 2 ton, calibration with test weights becomes impractical. Either it is physically impossible to hang test weights equal to the tank scale full capacity, or organizing the required amount of weights is not possible. For such cases, hydraulic equipment can be used to calibrate the scale.

Hydraulic equipment can be used in different ways, it can lift the tank (push-up), push the individual weigh modules downwards (push-down), or it can create the same downward force that is applied during calibration with test weights (pull-down). The latter is the most accurate among hydraulic calibration methods since it creates the same downward force and deflection that occur during normal operation, and therefore it accounts for the piping effects.

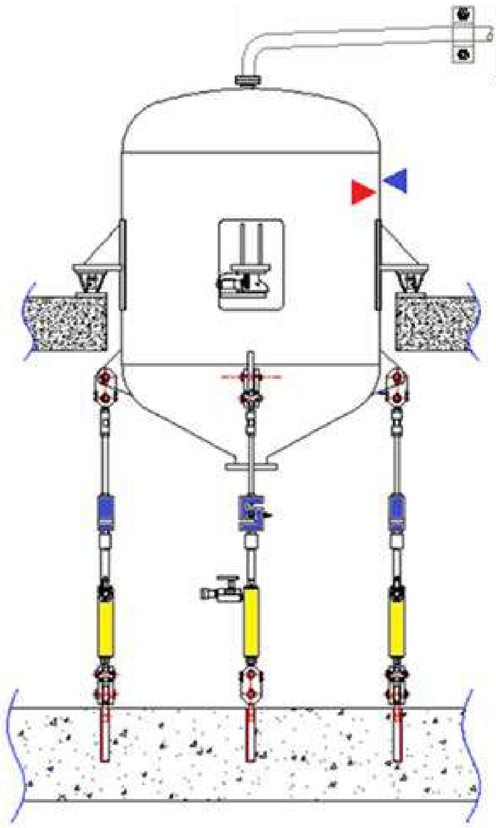
METTLER TOLEDO's RapidCal™ system utilizes the pull-down hydraulic calibration method. Instead of pulling down with test weights, this method pulls down with tension hydraulic cylinders in series with high-accuracy reference load cells to measure the calibration force applied. See a comparison of the two methods in the drawings below. Reference load cells are factory-calibrated with test weights in advance, making the calibration traceable to international mass standards.

For this method, the tank scale must be equipped with anchor points to attach the calibration equipment. The foundation underneath must have the same anchor points aligned vertically with their counterparts on the tank.

A tank scale can be calibrated without being fully empty with the calibration equipment being mounted to the exterior of the tank. Calibration is performed without opening the tank and without introduction of foreign materials, as is necessary in some other methods. In this way all possibility of tank contamination is avoided, there is no material to be disposed of, and no need to clean the tank before or after the operation.



A. Calibration using Test Weights



B. Calibration using RapidCal Modules

Electronic Calibration

Load Cell Simulator

A tank scale can be calibrated electronically using a load cell simulator. Attach the load cell simulator directly to the digital indicator in place of the home-run cable from the junction box. The simulator sends out a signal equal to the signal the load cells should produce. Electronic calibration is noted for its speed and simplicity; however, it calibrates only the electronics. Because it assumes that the tank and all mechanical connections are working properly, electronic calibration does not verify the scale's performance.

1. With the simulator adjusted to zero output, set the indicator to zero.
2. Adjust the simulator to full output (a signal equal to that which all the load cells should produce at their rated capacity).
3. Adjust the indicator to show the total capacity of all load cells in the system.
4. Attach the load cell input to the indicator.
5. Set the indicator to read zero for the empty weight of the tank.

CalFREE Electronic Calibration

The CalFREE™ program is another option for calibrating a scale without using test weights. This proprietary METTLER TOLEDO feature is built into the latest line of METTLER TOLEDO industrial indicators and is compatible with systems that use analog load cells rated at 2 mV/V or 3 mV/V.

The CalFREE program calculates the full-scale system output in millivolts to calibrate the scale electronically. For most analog scales, this value is nominally 2 or 3 millivolts output per volt of excitation at rated capacity. Due to manufacturing tolerances, the output or sensitivity of an individual load cell can vary slightly from these nominal values. The CalFREE program uses the summed average of the individual load cell sensitivities to determine the expected system output at rated capacity. The calibration certificate for each load cell lists the load cell's specific sensitivity at rated capacity.

A printed calibration certificate is supplied with each load cell that is shipped. Electronic copies of the calibration certificates can be downloaded from the following website:

http://calfree-cert.mt.com

To locate the calibration certificates for a scale, you will need to know the serial number of each load cell in the scale system. Calibration certificates are stored in PDF format by serial number. For example, the file for load cell serial number 6011154-6LH is 6011154-6LH.pdf.

Like a load cell simulator, the CalFREE procedure only calibrates the scale electronically. It does not compensate for mechanical influences such as piping attachments, movement in structural supports, vibration, etc.

CalFREE Plus Electronic Calibration

CalFREE Plus™ is an electronic calibration method developed for POWERCELL® systems.
This is a proprietary METTLER TOLEDO feature which is built in into compatible METTLER TOLEDO industrial indicators. POWERCELL® load cells contain the necessary information for an electronic calibration,and it is read automatically by the indicator. By doing that all error factors related to a human operator are eliminated.

Each POWERCELL® load cells are shipped with a printed calibration certificate too. Electroninc copies of the certificates can be downloaded from http://calfree-cert.com

Tank scale calibration methods

The table below lists advantages and disadvantages of various tank scale calibration methods, which can be used to make a decision on the later calibration method and design provisions accordingly.

Calibration method	Pros	Cons
Test weights	• Most accurate • Compensates effects of piping and flexible support structure • No contamination risk • Traceable	• Not practical at high capacities • Time consuming • Anchor points and space required to attach weights • Health and safety concerns
RapidCal™	• Good accuracy • Saves cost • Reduces downtime • No contamination risk • Good accuracy • Compensates effects of piping and flexible support structure • Traceable • No test weights required	• Anchor points required
Material substitution	• Medium accuracy • Compensates effects of piping and flexible support structure	• Time consuming • Contamination risk • Substitution material can be expensive • Disposal of substitution material
Material transfer	• Medium accuracy • Compensates effects of piping and flexible support structure • No test weights required	• Accuracy depends on reference scale and transfer method • Material must be transported • Material losses add to uncertainty • Not traceable
CalFree™ Plus	• Quick • No test weights required • No contamination risk • Automated calculations	• Low accuracy • Effects of piping and flexible support structure are not included • Not traceable
CalFree™	• Quick • No test weights required • No contamination risk	• Low accuracy • Effects of piping and flexible support structure are not included • Manual calculations, prone to operator errors • Not traceable

9. Indicators and Applications

Indicators

The basic job of a scale indicator is to receive the signal transmitted by the load cells and display it as a weight reading. For process weighing applications, indicators must provide fast, repeatable weight readings that remain stable at relatively high resolutions. But in many cases, the key factor in selecting an indicator is its ability to communicate with the process control equipment used for a specific application.

Communications

What type of communications capabilities an indicator needs depends on how you plan to use the weight data provided by the scale. For a very simple process, an indicator might use setpoints to tell an operator when to manually fill or empty a tank. For an automated process, the setpoints could actually control valves or feeders. For more complex systems, an indicator might need to interact with a programmable logic controller (PLC) that runs an entire processing operation.

An indicator's ability to interact with other equipment is determined by its communication inputs and outputs. The types of inputs and outputs are described below:

Discrete Input/Output
Discrete inputs are connections used to trigger a command or action in a scale indicator. Typical commands are Clear, Tare, Print, Zero, switch weight units, switch scales, and disable weight display.

Discrete outputs are connections used to relay on/off information from the indicator. They do not transmit actual weight values. Discrete outputs can be used for setpoints or scale status information such as scale in motion, zero, under zero, over capacity, and net/gross weighing mode. Because they are a direct connection from the indicator to the output device, these outputs operate very quickly.

Analog Output
Analog output is the variable signal of milliamp current or DC voltage that represents a weight value, which can be used by a PLC located up to 50 ft [15m] from the indicator. The weight data is converted several times during its transmission from load cells to PLC, with the signal losing a percentage of its accuracy for each conversion.

Serial Communication Output
Serial communication ports are used to send weight data from the scale to a remote display, fill valves, computer, PLC, printer, or other equipment. These outputs can transmit information about scale status, scale capacity, increment size, setpoint status, weight unit, and net/gross weighing mode. Serial outputs can transmit more information than discrete outputs but have a slower update rate. Long cabling distances are possible, but connection with a PLC requires additional hardware/software.

These outputs can communicate in demand, continuous, or host mode. Demand mode sends weight data to a printer or other device only when requested. Continuous mode transmits weight data repeatedly to a remote display or other device. Host mode allows two-way communication between the scale and a host computer.

Direct PLC Interface
A direct PLC interface makes it possible to transmit the following types of information:
- Weight Data: gross, tare, net, rate.
- Status Data: motion, net mode, setpoints, data integrity.
- Commands: tare, clear, print, zero, load setpoint, load tare, control display messages.
- Floating Point Data: special format with additional data and commands.

It requires a special printed circuit board (PCB) to interface with a specific manufacturer's PLC. The following options are available for METTLER TOLEDO IND130, IND560, IND780, and PANTHER indicators:
- Allen-Bradley™ RIO – This PCB enables an indicator to operate as an Allen-Bradley remote input/output (RIO) device. It allows discrete transfer of data from the indicator to the PLC and block transfer of data between the PLC and other devices.
- Profibus™-DP – This PCB enables an indicator to communicate with a Siemens or Texas Instruments PLC. Discrete data can be input or output in large blocks.
- Modbus TCP – This PCB enables an indicator to communicate with a Modbus TCP network. It allows bi-directional discrete mode communications.
- ControlNet – This PCB enables an indicator to communicate with a ControlNet PLC through direct connection to the ControlNet network. It allows bi-directional discrete mode communications.
- Ethernet/IP – This PCB enables an indicator to communicate with an Ethernet/IP PLC through direct connection to the Ethernet/IP network at 10 or 100 MBPS speed. It allows bi-directional discrete mode communications.
- DeviceNet – DeviceNet is an RS-485-based network using CAN chip technology. It was created for bit- and byte-level devices.

Weighing Accuracy

Dynamic Weighing
Vibration or motion on a scale can make it difficult to get an accurate weight reading. For dynamic weighing applications where the load on a scale is constantly in motion, indicators need to be able to take a series of weight readings and use those readings to calculate an average weight.

Filtering
Environmental noise is vibration caused by nearby machinery, unstable structures, or wind and air currents. Instead of calculating an average weight reading, most indicators can filter out this noise. An indicator with a wide range of filtering levels usually can provide the best combination of noise reduction and update speed.

Applications

Figure 9-1a and 9-1b show a typical weigh module system with the indicator connected to a customer's PLC for both Analog and Powercell systems .

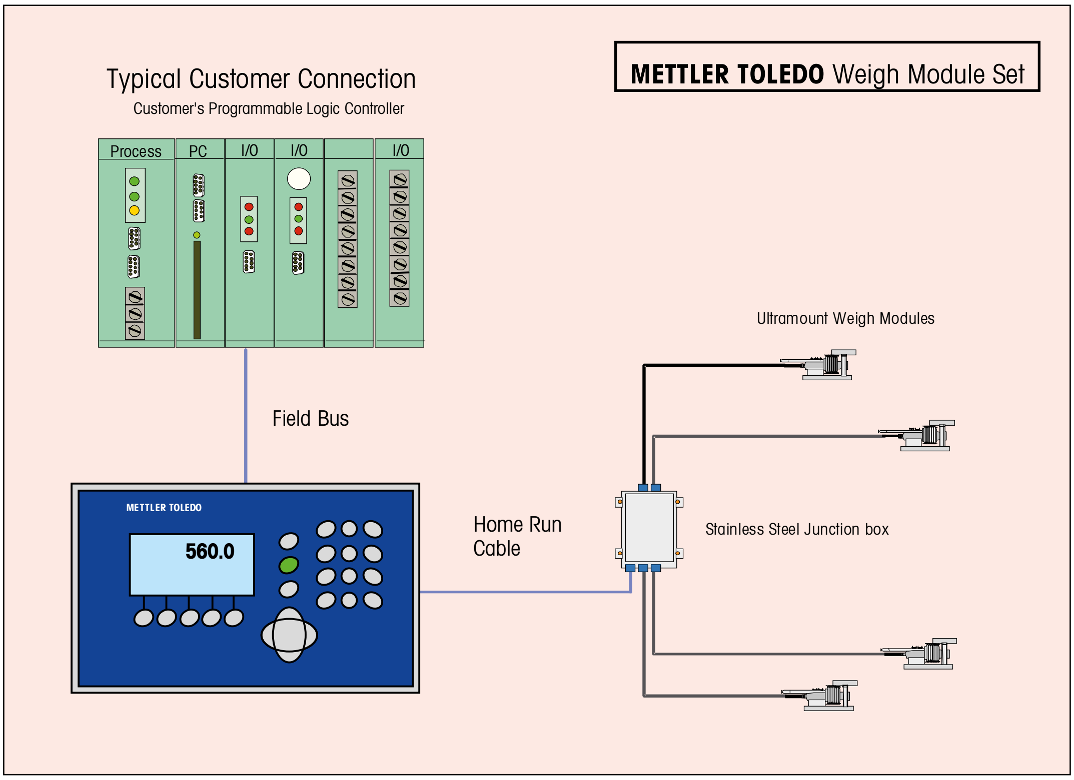


Figure 9-1a: Typical Weigh Module System

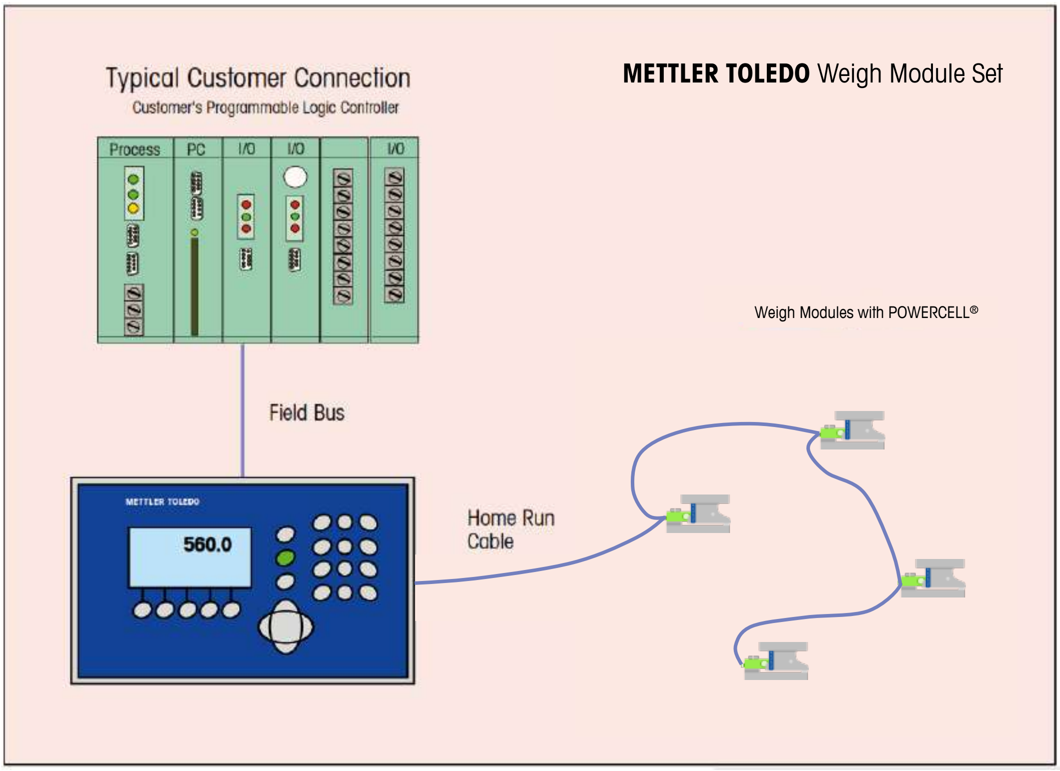


Figure 9-1b: Typical Weigh Module System with POWERCELL® load cells

Figure 9-2 shows a weigh module system for a hazardous environment. The weigh module system is located within a hazardous area barrier and connected to an indicator and PLC in a safe area.

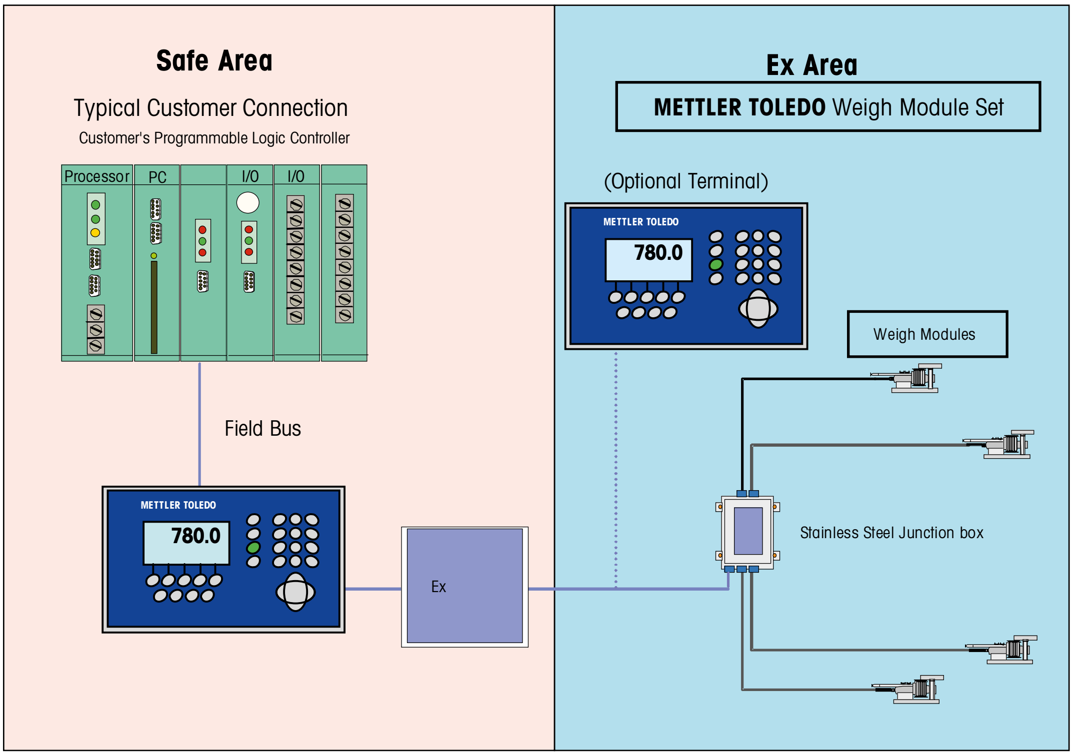


Figure 9-2: Weigh Module System for a Hazardous Environment

Figure 9-3 shows an overview of sample weigh module systems.

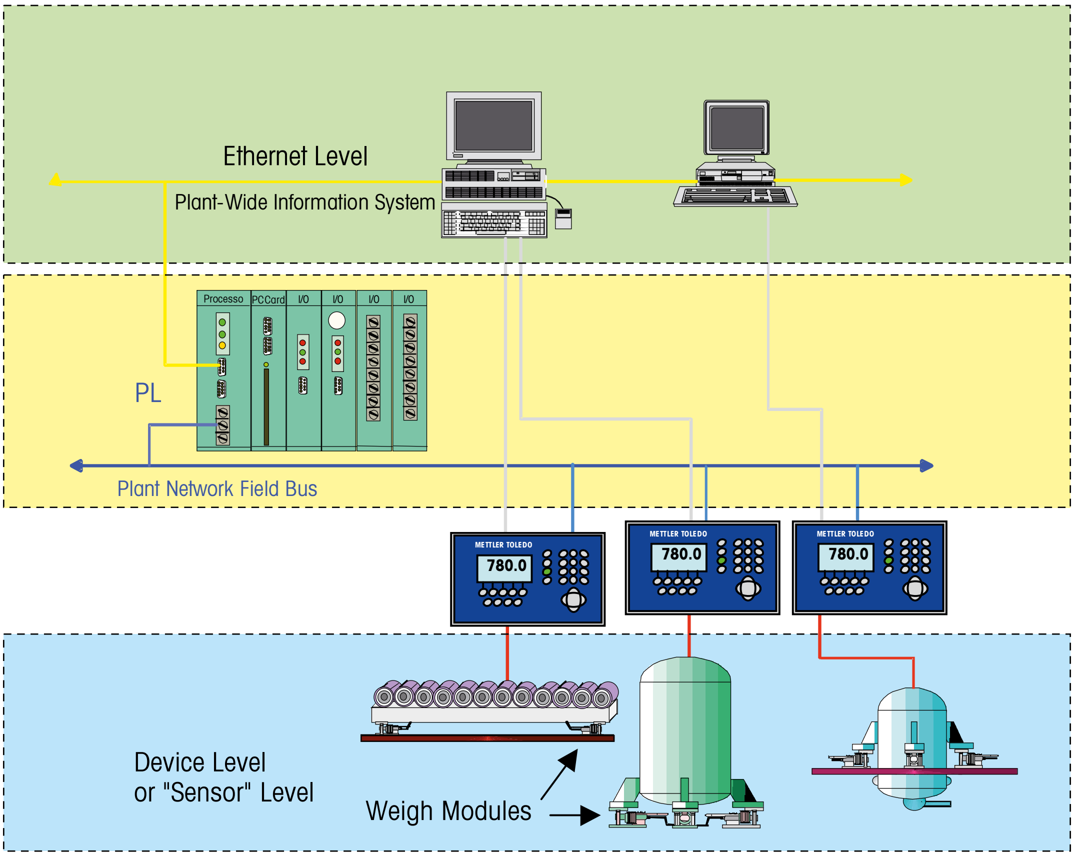


Figure 9-3: Overview of Weigh Module Systems

10. Appendices

Appendix 1: Design Qualification Form

When planning a weigh module application, use the design qualification form on the next page to list the system requirements that need to be considered.

METTLER TOLEDO Weigh Module Design Qualification Form

Include the unit of measure used below

1. Type: Tank ____________ Hopper ____________ Vessel ____________ Silo ____________ Other ____________

2. Dimensions: Length ___________ Width ___________ Height ___________ (square or rectangular)

Diameter __________ Height (vertical tank)__________ Length (horizontal tank) __________ (cylindrical)

3. Number of supports (Legs / Lugs / Suspension Rods):

4. Distance between supports:

5. Dimension of Legs / Rods: Length ___________ Width (dia.) ___________ Height ____________

6. Gross capacity: | 7. Empty Weight:

8. Nominal load cell capacity:

9. Required system resolution (increment size):

10. Seismic conditions? Yes _____ No _____

12. Is system located outdoors? Yes _____ No _____

14. Is the tank or vessel jacketed? Yes _____ No _____

15. Jacket will contain: Coolant _____ Type ___________ Heat source _____ Type ___________

16. Does jacket continuously circulate? Yes _____ No _____

17. Is there an agitator? Yes _____ No _____ | 18. Size of Motor__________

18. Will agitator be required to cycle when taking weight readings? Yes _____ No _____

19. What is the ambient temperature for the area of operation? Min. ___________ Max. ___________

20. If a reactor vessel, what are the internal temperatures? Min. ___________ Max. ___________

21. Number of piping terminations (inlets/outlets) to the vessel that are: Rigid________Flexible_________

22. How many are: Horizontal to vessel ___________ Vertical to vessel ____________

23. Is the vessel vented? Yes _____ No _____

24. Is the area of operation Hazardous/Classified? Yes _____ No _____

25. If yes, state: Class ___________ Division ____________ Group ___________or Zone____________

26. Autoignition temperature of the product to be weighed:

26a. Load cells to be mounted in: Compression_______Tension________

27. Load cells to be mounted on: Concrete floor _____ Structural Steel_____ Mezzanine _____Other_______

28. Length of cable required from vessel to indicator (Home Run Cable): ___________

29. Provisions on the tank, vessel, or hopper to hang calibration weights? Yes _____ No _____

Prepared By	Date	Approved By	Date

Appendix 2: Calculating Reaction Forces

The effect of wind or seismic events on a tank is defined in terms of reaction forces (downward, upward, and shear). For the sample application used in this appendix, we will assume that the total horizontal shear equals the equivalent force applied at the tank's center of gravity (c.g.). Wind and seismic forces are discussed in Chapter 4.

> **⚠ CAUTION**
>
> THE FOLLOWING CALCULATIONS ARE PROVIDED AS GUIDELINES ONLY. THEY SHOULD NOT REPLACE A STRUCTURAL ENGINEERING EVALUATION OF THE APPLICATION BY A REGISTERED PROFESSIONAL ENGINEER WHO IS FAMILIAR WITH LOCAL BUILDING CODES.

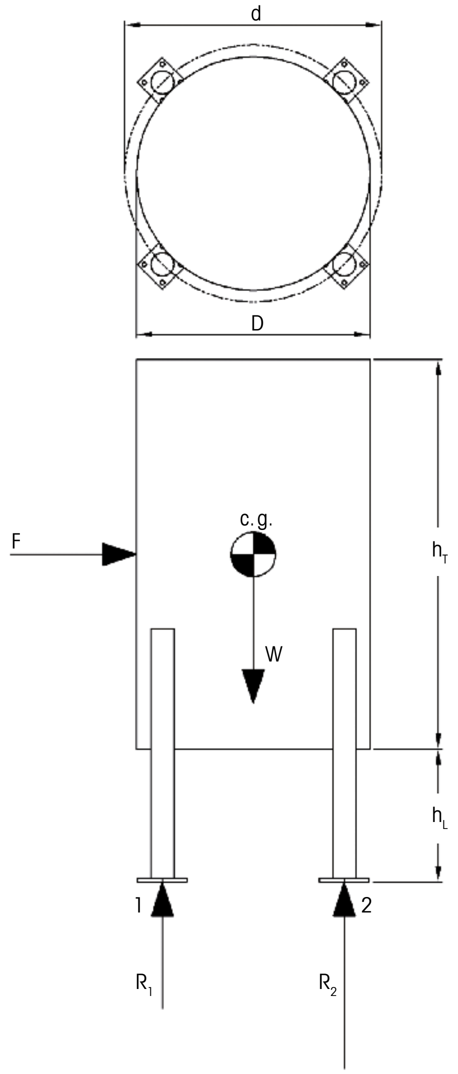
Vertical reaction forces are calculated using statics, which is the study of bodies at rest (equilibrium). The following factors are used to calculate reaction forces for the tank scale shown in Figure 10-1:

- h_T = Height of Tank in ft [m].
- h_L = Height of Tank's Legs in ft [m]
- d = Diameter of the circle drawn between the points at which the weigh modules support the tank scale, in ft [m].
- D = Diameter of Tank in ft [m]
- W = Weight of Tank & Contents at any time in lb [kgf]
- W_{Empty} = Weight of Empty Tank in lb [kgf]
- W_{Full} = Weight of Tank when Full (tank and contents) in lb [kgf]
- $R_{1,2}$ = Vertical Reaction Forces at Weigh Modules in lb [kgf]
- F = Horizontal Force due to Wind or Seismic Event (applied at tank c.g.) in lb [kgf]

Note regarding metric units of measure. Since load cells and weigh modules are rated in units of mass, it is more convenient here to calculate the reaction forces at the weigh modules in kgf. 1kgf = 9.81N

Circular Tank with Four Weigh Modules

The following example shows how statics is used to calculate reaction forces for a vertical cylindrical tank with four weigh modules, as shown in Figure 10-1.



R_1 and R_2 are the vertical forces that must be applied by the weigh modules (not shown) to support the tank. Equal and opposite forces are applied by the tank to the weigh modules. Horizontal forces at 1 and 2 are not shown.

Figure 10-1: Free-Body diagram,
vertical cylindrical Tank with Four Weigh Modules

As drawn in Figure 10-1 above, F will reduce the weight on the weigh modules on side 1 while the weight will be increased on side 2. There are 2 things to check, that the weigh modules on side 1 are not loaded excessively in uplift and that the modules on side 2 are not overloaded.

If the tank is in equilibrium, the sum of the moments about side 2 will equal zero ($\sum M_2 = 0$), hence

$$W \times (d/2) \times \sin 45° = (h_L + 0.5 \times h_T) \times F + 2 \times R_1 \times d \times \sin 45°$$

Solve for R_1

$$R_1 = W/4 - 0.71 \times (h_L + 0.5 \times h_T) \times F/d \quad (1)$$

Also the sum of the forces in the Y (vertical) direction will equal zero ($\sum F_Y = 0$), hence

$$2 \times R_1 + 2 \times R_2 = W, \text{ or}$$

$$R_2 = W/2 - R_1$$

Substitute for R_1 from Equation (1) above and solve for R_2:

$$R_2 = W/4 + 0.71 \times (h_L + 0.5 \times h_T) \times F/d \quad (2)$$

Under normal circumstances without F acting, $R_1 = R_2 = W/4$. With F acting it can be seen from equation (1) that R_1 is reduced by the factor

$$0.71 \times (h_L + 0.5 \times h_T) \times F/d$$

and from equation (2) that R_2 is increased by the same amount.

Note that the only difference between equations (1) and (2) is the sign between the two terms on the right hand side; in other words, the effect of the horizontal force F is to transfer weight of $0.71 \times (h_L + 0.5 \times h_T) \times F/d$ from each of the modules on side 1 to each of the modules on side 2. Up to the point of uplift the sum $2R_1 + 2R_2$ will always equal W, that is theoretically at least, a purely horizontal force shifts weight between the weigh modules but has no influence on the scale weight reading, see also Scale Performance in Chapter 4, Weigh Module Environmental Considerations. After uplift and the engagement of an anti-uplift device, other vertical forces come into play and this is no longer valid.

From equation (1) R_1 will be zero when

$$0.71 \times (h_L + 0.5 \times h_T) \times F/d = W/4$$

or solving for F,

$$F = 0.35 \times W \times d / (h_L + 0.5 \times h_T) \quad (3)$$

The tank will be about to lift off the weigh modules at side 1 when F reaches this value.

For a given F value, R_1 will be a minimum when the tank is empty ($W = W_{Empty}$) thus from equation (1)

$$R_{1Min} = (W_{Empty})/4 - 0.71 \times (h_L + 0.5 \times h_T) \times F/d \quad (4)$$

and this represents the greatest risk of an uplift force being applied to the weigh modules at side 1, see note at end. Use equation (4) to calculate R_{1Min}; if the result is positive there remains a downward force on the weigh modules; if negative there is an uplift force applied to the weigh modules at side 1 and this must not exceed the "Max. Uplift Force" rating for the weigh modules. If it does, you must use a weigh module with higher "Max. Uplift Force" rating or install external checking.

For a given F value, R_2 will be a maximum when the tank is full ($W = W_{Full}$) thus from equation (2)

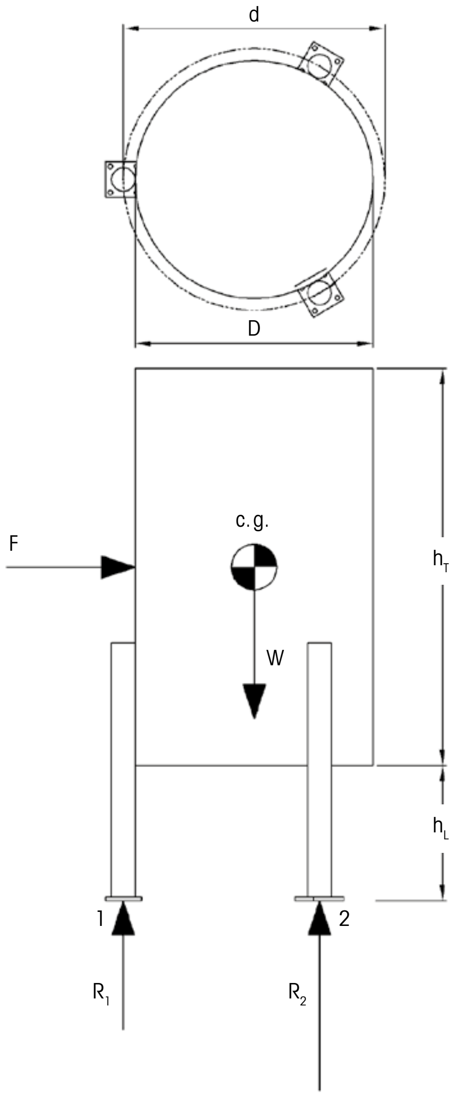
$$R_{2Max} = (W_{Full})/4 + 0.71 \times (h_L + 0.5 \times h_T) \times F/d \quad (5)$$

and this represents the greatest risk of an overload being applied to the weigh modules at side 2, see note at end. Use equation (5) to calculate R_{2Max} which should not exceed the weigh modules' "Rated Capacity", if it does there is a danger of damage to the load cells through overload; fix this by selecting weigh modules with a higher "Rated Capacity".

Note: In the case of wind and seismic loading it is typical to assume that the force can be applied in any direction. In Figure 10-1 the effect of a horizontal force acting at 45 degrees to the direction of F should also be investigated.

Circular Tank with Three Weigh Modules

The following example shows how statics is used to calculate reaction forces for an outdoor installation of a vertical cylindrical tank with three weigh modules.



R_1 and R_2 are the vertical forces that must be applied by the weigh modules (not shown) to support the tank. Equal and opposite forces are applied by the tank to the weigh modules. Horizontal forces at 1 and 2 are not shown.

Figure 10-2: Free-Body diagram, vertical cylindrical Tank with Three Weigh Modules

As drawn in Figure 10-2 above, F will reduce the weight on the weigh module on side 1 while the weight will be increased on side 2. There are 2 things to check, that the weigh module on side 1 is not loaded excessively in uplift and not overloaded if the wind direction rotates 180 degrees.

If the tank is in equilibrium, the sum of the moments about side 2 will equal zero ($\sum M_2 = 0$), hence

$$W \times (d/2) \times \sin 30° = (h_L + 0.5 \times h_T) \times F + R_1 \times d \times (1 + \sin 30°)/2$$

Solve for R_1

$$R_1 = W/3 - 1.33 \times (h_L + 0.5 \times h_T) \times F/d \quad (6)$$

Also the sum of the forces in the Y (vertical) direction will equal zero ($\sum F_Y = 0$), hence

$$R_1 + 2 \times R_2 = W, \text{ or}$$
$$R_2 = W/2 - R_1/2$$

Substitute for R_1 from Equation (6) above and solve for R_2:

$$R_2 = W/3 + 0.67 \times (h_L + 0.5 \times h_T) \times F/d \quad (7)$$

Under normal circumstances without F acting, $R_1 = R_2 = W/3$. With F acting it can be seen from equation (6) that R_1 is reduced by the factor

$$1.33 \times (h_L + 0.5 \times h_T) \times F/d$$

and from equation (7) R_2 is increased by $0.67 \times (h_L + 0.5 \times h_T) \times F/d$. The weight transferred from R_1 is shared by the two weigh modules on side 2.

Up to the point of uplift the sum $R_1 + 2R_2$ will always equal W, that is, a purely horizontal force shifts weight between the weigh modules but has no influence on the scale weight reading, see also Scale Performance in Chapter 4, Weigh Module Envirationmental Considerations. After uplift and the engagement of an anti-uplift device, other vertical forces come into play and this is no longer valid.

From equation (6) R_1 will be zero when

$$1.33 \times (h_L + 0.5 \times h_T) \times F/d = W/3$$

or solving for F:

$$F = 0.25 \times W \times d/(h_L + 0.5 \times h_T) \quad (8)$$

The tank will be about to lift off the weigh module at side 1 when F reaches this value.

For a given F value, R_1 will be a minimum when the tank is empty ($W = W_{Empty}$) thus from equation (6)

$$R_{1Min} = (W_{Empty})/3 - 1.33 \times (h_L + 0.5 \times h_T) \times F/d \quad (9)$$

and this represents the greatest risk of an uplift force being applied. Use equation (9) to calculate R_{1Min}; if the result is positive there is a downward force on the weigh module at side 1. If R_{1Min} is negative then there is an uplift force applied and this must not exceed the "Max. Uplift Force" rating for the weigh module. If it does you must use a weigh module with higher "Max. Uplift Force" rating or install external checking.

The weight $1.33 \times (h_L + 0.5 \times h_T) \times F/d$ is transferred from the single weigh module at side 1 and is shared between the 2 weigh modules on side 2. From an overload perspective the worst case occurs if the wind direction changes 180° from that shown in Figure 10-2, causing transferred weight to be applied to the single weigh module at side 1. In this case it can be shown readily by taking moments about side 2 that:

$$R_1 = W/3 + 1.33 \times (h_L + 0.5 \times h_T) \times F/d \quad (10)$$

Force F causes R_1 to be increased by the factor

$$1.33 \times (h_L + 0.5 \times h_T) \times F/d.$$

For a given F value, R_1 will be a maximum when the tank is full ($W = W_{Full}$) thus from equation (10)

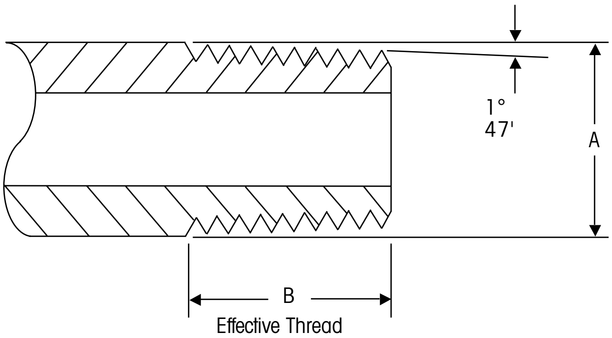
$$R_{1Max} = (W_{Full})/3 + 1.33 \times (h_L + 0.5 \times h_T) \times F/d \quad (11)$$

and this represents the greatest risk of an overload being applied. Use equation (11) to calculate R_{1Max} which should not exceed the weigh modules' "Rated Capacity", if it does there is a danger of damage to the load cells through overload; fix this by selecting weigh modules with a higher "Rated Capacity".

Appendix 3: Bolt Thread Dimensions

The following tables list National Pipe Taper (NPT) dimensions and dimensions for hex head bolts.

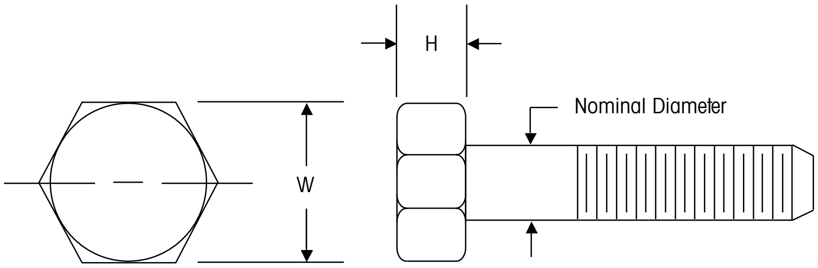
NPT Dimensions



NPT Size	Threads Per Inch	A (inches)	B (inches)
1/16	27	0.312	0.261
1/8	27	0.405	0.264
1/4	18	0.540	0.402
3/8	18	0.675	0.408
1/2	14	0.840	0.534
3/4	14	1.050	0.546
1	11 1/2	1.315	0.683
1 1/4	11 1/2	1.660	0.707

Table 10-1: NPT Dimensions

Bolt Dimensions



Imperial

Nominal Bolt Size	Threads per Inch		Nominal Diameter	W (inches)	H (inches)
	Coarse (UNC)	Fine (UNF)			
6	32	40	0.1380	–	–
8	32	36	0.1640	–	–
10	24	32	0.1900	–	–
12	24	28	0.2160	–	–
1/4	20	28	0.2500	7/16	11/64
5/16	18	24	0.3125	1/2	7/32
3/8	16	24	0.3750	9/16	1/4
7/16	14	20	0.4375	5/8	19/64
1/2	13	20	0.5000	3/4	11/32
9/16	12	18	0.5625	13/16	3/8
5/8	11	18	0.6250	15/16	27/64
3/4	10	16	0.7500	1 1/8	1/2
7/8	9	14	0.8750	1 5/16	37/64
1	8	12	1.0000	1 1/2	43/64
1 1/8	7	12	1.1250	1 11/16	3/4
1 1/4	7	12	1.2500	1 7/8	27/32
1 3/8	6	12	1.3750	2 1/16	29/32
1 1/2	6	12	1.5000	2 1/4	1

Metric

Nominal Bolt Size*	Thread Pitch (mm)	Nominal Diameter	W (mm)	H (mm)
M3	0.5	3	5.5	2.125
M4	0.7	4	7.0	2.925
M5	0.8	5	8.0	3.650
M6	1	6	10.0	4.150
M8	1.25	8	13.0	5.650
M10	1.5	10	17.0	7.180
M12	1.75	12	19.0	8.180
(M14)	2	14	22.0	9.180
M16	2	16	24.0	10.180
(M18)	2.5	18	27.0	12.215
M20	2.5	20	30.0	13.215
(M22)	2.5	22	32.0	14.215
M24	3	24	36.0	15.215
(M27)	3	27	41.0	17.215
M30	3.5	30	46.0	19.260
(M33)	3.5	33	50.0	21.260
M36	4	36	55.0	23.260
(M39)	4	39	60.0	25.260

*Bolt sizes shown in parentheses are not preferred.

Table 10-2: Bolt Dimensions

Appendix 4: NEMA/IP Enclosure Types

The National Electrical Manufacturers Association (NEMA) provides descriptions, classifications, and test criteria relating to enclosures for electrical equipment. Tables 10-3, 10-4, and 10-5 compare the specific applications of enclosures for indoor and outdoor nonhazardous locations and indoor hazardous locations.

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	1*	2*	4	4X	5	6	6P	12	12K	13
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (falling dirt)	X	X	X	X	X	X	X	X	X	X
Ingress of water (dripping and light splashing)		X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (circulating dust, lint, fibers, and flyings**)			X	X		X	X	X	X	X
Ingress of solid foreign objects (settling airborne dust, lint, fibers, and flyings**)			X	X	X	X	X	X	X	X
Ingress of water (hosedown and splashing water)			X	X		X	X			
Oil and coolant seepage								X	X	X
Oil or coolant spraying and splashing										X
Corrosive agents				X			X			
Ingress of water (occasional temporary submersion)						X	X			
Ingress of water (occasional prolonged submersion)							X			

*These enclosures may be ventilated.
**These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings, see the National Electrical Code, Article 500.

Table 10-3: Specific Applications of Enclosures for Indoor Nonhazardous Locations

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	3	3X	3R*	3RX*	3S	3SX	4	4X	6	6P
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of water (rain, snow, and sleet**)	X	X	X	X	X	X	X	X	X	X
Sleet***					X	X				
Ingress of solid foreign objects (windblown dust, lint, fibers, and flyings)	X	X			X	X	X	X	X	X
Ingress of water (hosedown)							X	X	X	X
Corrosive agents		X		X		X		X		X
Ingress of water (occasional temporary submersion)									X	X
Ingress of water (occasional prolonged submersion)										X

*These enclosures may be ventilated.
**External operating mechanisms are not required to be operable when the enclosure is ice covered.
***External operating mechanisms are operable when the enclosure is ice covered.

Table 10-4: Specific Applications of Enclosures for Outdoor Nonhazardous Locations

Provides a Degree of Protection Against Atmospheres Typically Containing:*		Enclosure Types 7 & 8 Class I Groups***				Enclosure Type 9 Class II Groups			
	Class	A	B	C	D	E	F	G	10
Acetylene	I	X							
Hydrogen, manufactured gas	I		X						
Diethyl ether, ethylene, cyclopropane	I			X					
Gasoline, hexane, butane, naphtha, propane, acetone, toluene, isoprene	I				X				
Metal dust	II					X			
Carbon black, coal dust, coke dust	II						X		
Flour, starch, grain dust	II							X	
Fibers, flyings**	III							X	
Methane with or without coal dust	MSHA								X

*For complete listing, see NFPA 497M.
**For Class III type ignitable fibers or combustible flyings, see the National Electrical Code, Article 500.
***Due to the characteristics of the gas, vapor, or dust, a product suitable for one Class or Group may not be suitable for another Class or Group unless marked on the product.

Table 10-5: Specific Applications of Enclosures for Indoor Hazardous Locations

Tables 10-6 and 10-7 describe the types of enclosures, their applications, and the environmental conditions they are designed to provide protection against.

NEMA Type	Description
1	Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts and to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt).
2	Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).
3	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and that will be undamaged by the external formation of ice on the enclosure.
3R	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and that will be undamaged by the external formation of ice on the enclosure.
3S	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and for which the external mechanism(s) remain operable when ice laden.
3X	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.
3RX	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that will be undamaged by the external formation of ice on the enclosure, that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.
3SX	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that provides an additional level of protection against corrosion; and for which the external mechanism(s) remain operable when ice laden.

NEMA Type	Description
4	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose-directed water); and that will be undamaged by the external formation of ice on the enclosure.
4X	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose-directed water); that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.
5	Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and settling airborne dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).
6	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose-directed water and the entry of water during occasional temporary submersion at a limited depth); and that will be undamaged by the external formation of ice on the enclosure.
6P	Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose-directed water and the entry of water during prolonged submersion at a limited depth); that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.
12	Enclosures constructed (without knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).
12K	Enclosures constructed (with knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).
13	Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against the spraying, splashing, and seepage of oil and non-corrosive coolants.

Table 10-6: Nonhazardous Area Enclosures

NEMA Type	Description	Requirements/Design Tests*
7	Enclosures constructed for indoor use in hazardous (classified) locations classified as Class I, Division 1, Groups A, B, C, or D as defined in NFPA 70.	ANSI/UL 698, ANSI/UL 877, ANSI/UL 886, ANSI/UL 894
8	Enclosures constructed for either indoor or outdoor use in hazardous (classified) locations classified as Class I, Division 1, Groups A, B, C, and D as defined in NFPA 70.	ANSI/UL 698, ANSI/UL 877, Rain
9	Enclosures constructed for indoor use in hazardous (classified) locations classified as Class II, Division 1, Groups E, F, or G as defined in NFPA 70.	ANSI/UL 698, ANSI/UL 877, ANSI/UL 886, ANSI/UL 894
10	Enclosures constructed to meet the requirements of the Mine Safety and Health Administration, 30 CFR, Part 18.	In accordance with the Mine Safety and Health Administration

Table 10-7: Hazardous Area Enclosures

The International Electrotechnical Commission (IEC) provides international classifications (IP Codes) of enclosures for electrical equipment. Table 10-8 can be used to convert NEMA Enclosure Type Numbers to IEC Enclosure Classification Designations. However, since NEMA Types meet or exceed the test requirements for the IEC Classifications, this table cannot be used to convert IEC Classifications to NEMA Types.

IP First Character	NEMA Enclosure Type																		IP Second Character
	1		2		3, 3X, 3S, 3SX		3R, 3RX		4, 4X		5		6		6P		12, 12K, 13		
IP0_	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	IP_0
IP1_	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	IP_1
IP2_	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	IP_2
IP3_					X	X		X	X	X	X	X	X	X	X	X	X	X	IP_3
IP4_					X	X		X	X	X	X		X	X	X	X	X	X	IP_4
IP5_					X	X			X	X	X		X	X	X	X	X		IP_5
IP6_									X	X			X	X	X	X			IP_6
														X		X			IP_7
																X			IP_8
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	

Table 10-8: Conversion of NEMA Type Numbers to IEC Classification Designations

An "X" in column A indicates that the NEMA enclosure type exceeds the requirements for the respective IEC 60529 IP first character designation (protection against access to hazardous parts and solid foreign objects). An "X" in column B indicates that the NEMA enclosure type exceeds the requirements for the respective IEC 60529 IP second character designation (protection against the ingress of water). To meet or exceed an IP rating, a NEMA enclosure type must meet or exceed the requirements for both the first character (column A) and the second character (column B). For example, suppose an IEC IP45 enclosure rating is specified. The following NEMA type enclosures meet or exceed the IP45 rating: 3, 3X, 3S, 3SX, 4, 4X, 6, 6P.

Table 10-9 provides a brief description of the IP Code.

First Character (Protection against solid objects)	Second Character (Protection against liquids)
0 = No protection	0 = No protection
1 = Protection against solid objects > 2 in [50 mm] (for example, hands)	1 = Protection against falling drops of water
2 = Protection against solid objects > 0.5 in [12.5 mm] (for example, fingers)	2 = Protection against falling drops of water with enclosure tilted up to 15°
3 = Protection against solid objects > 0.1 in [2.5 mm] (for example, tools and wires)	3 = Protection against direct spray of water
4 = Protection against solid objects > 0.04 in [1 mm]	4 = Protection against water splashed from any direction
5 = Protection against dust (limited ingress)	5 = Protection against low-pressure jets of water
6 = Totally protected against dust	6 = Protection against strong jets of water
	7 = Protection against 6 to 40 in [15 to 100 cm] immersion
	8 = Protection against long periods of immersion
	9K = Protection against high-pressure water jets from all directions, 3.7 to 4.2 US gallons/min [14 to 16 l/min], 1160 to 1450 psi [8000 to 10000 kPa], 176°F [80°C], 30 sec, 4 to 6 in [10 to 15 cm] distance. METTLER TOLEDO tests according to DIN 400050 part 9.

Table 10-9: Details of the Standard IEC/EN60529

Appendix 5: Classification of Hazardous Areas

North America

In North America (United States and Canada) there are two codes for explosive area classification or Hazloc (hazardous location) classification, one based on class/divisions and one based on zones. The most commonly found is the class/division classification based on the NEC 500 legislation in the United States and on CEC Section 18 Annex J legislation in Canada (see Table 10-10). The class defines the type of hazard present (gas/dust) and the explosive characteristic of the materials present. The division is based on the occurrence of risk these hazardous materials present. In North America there also exists a zone classification system based on the IEC guidelines and supported by the NEC 505 legislation and the CEC Section 18 legislation (see Table 10-11). Here the risk is divided into three zones rather than two divisions. Currently, however, the zoning system applies only to gas and vapor hazards.

Substance	Division	
Class I Gases Vapors	Division 1	Areas in which dangerous concentrations of flammable gases/vapors are present continuously or occasionally under normal operating conditions.
	Division 2	Areas in which dangerous concentrations of flammable gases/vapors are not likely to be present under normal operating conditions.
Class II Dusts	Division 1	Areas in which dangerous concentrations of flammable dusts are present continuously or occasionally under normal operating conditions.
	Division 2	Areas in which dangerous concentrations of flammable dusts are not likely to be present under normal operating conditions.
Class III Fibers Flyings	Division 1	Areas in which dangerous concentrations of flammable fibers and flyings are present continuously or occasionally under normal operating conditions.
	Division 2	Areas in which dangerous concentrations of flammable fibers and flyings are not likely to be present under normal operating conditions.

Table 10-10: Hazardous Area Classes and Divisions, North America

Substance	NEC 505	Zoning		Equipment Category
Gases Vapors	Class 1	Zone 0	Area in which an atmosphere at risk of explosion from gases or vapors is continuously or frequently present during normal operation.	1G
		Zone 1	Area in which an atmosphere at risk of explosion from gases or vapors can form occasionally during normal operation.	2G (1G)*
		Zone 2	Area in which an atmosphere at risk of explosion from gases or vapors does not normally form or forms for only short periods during normal operation.	3G (1G & 2G)*
Dusts	No NEC classification	Zone 20	Area in which an atmosphere at risk of explosion from flammable dust is continuously or frequently present during normal operation.	1D
		Zone 21	Area in which an atmosphere at risk of explosion from flammable dust can form occasionally during normal operation.	2D (1D)*
		Zone 22	Area in which an atmosphere at risk of explosion from flammable dust does not normally form or forms for only short periods during normal operation.	3D (1D & 2D)*
*Approved products can also be used.				

Table 10-11: Hazardous Area Zones, North America, Europe and International

Explosive atmospheres can be found in the form of gases, vapors, mists, or dusts which can ignite under certain operating conditions. Potentially explosive atmospheres are found in many industries and all of these have the potential to produce gas, dust, or fumes which can be ignited by an ignition source.

Europe and International

In Europe the areas are classified into zones as shown in Table 10-11 using the ATEX legislation. This legislation is based on methods developed by the International Electric Council (IEC) with the aim of creating one global standard. The European Committee for Electrotechnical Standardization (CENELEC) and the IEC agreed in 1994 to combine standards wherever possible, and this led to the ATEX standards being almost identical to the IEC standards. There are, however, some differences, and the harmonization process is still ongoing. The IEC standards are frequently being adopted by national approval agencies such as NEPSI in China. This makes gaining local approvals easier. No single, internationally recognized and accepted standard exists at this time. Global agencies are committed to harmonizing standards, but it will be a long time before this becomes a reality.

Appendix 6: Chemical Resistance Chart

The following chemical resistance chart is provided as a guide to help select materials for weigh module system components and hardware. The information is reprinted courtesy of Little Giant Pump Company.

These recommendations are based on information from material suppliers and careful examination of available published information and are believed to be accurate. However, since the resistance of metals, plastics, and elastomers can be affected by concentration, temperature, presence of other chemicals, and other factors, this information should be considered as a general guide rather than an unqualified guarantee. Ultimately, the customer must determine the suitability of the materials used in various environments.

All recommendations assume ambient temperatures unless otherwise noted. The ratings for these materials are based on the chemical resistance only. Added consideration must be given to material selection when the chemical is abrasive, viscous in nature, or has a Specific Gravity greater than 1.1.
Note: Ceramagnet "A" is generically known as barium ferrite.

Ratings – Chemical Effect

A – No effect – Excellent
B – Minor effect – Good
C – Moderate effect – Fair
D – Severe effect – Not Recommended

Footnotes

1. PVC – Satisfactory to 72°F [22°C]
2. Polypropylene – Satisfactory to 72°F [22°C]
3. Polypropylene – Satisfactory to 120°F [49°C]
4. Buna-N – Satisfactory for O-Rings
5. Polyacetal – Satisfactory to 72°F [22°C]
6. Ceramag – Satisfactory to 72°F [22°C]
7. See Appendix 7 for equivalent stainless steel designations

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Acetaldehyde[5]	A	A	A	-	B	A	A	D	-	-	C	-	D	D	A	-	A	A	D	C	B	A	A	A	-	D	B	B	D	B	C	A
Acetamide	-	B	A	-	-	-	-	-	-	-	C	-	-	-	-	-	B	-	-	-	-	-	-	A	-	A	A	-	A	A	D	A
Acetate Solv.[2]	A	B	A	B	B	-	-	A	C	B	A	-	B	D	A	-	-	A	-	B	D	-	A	A	-	D	D	-	D	-	-	A
Acetic Acid, Glacia[1]	-	B	A	A	B	A	A	C	C	D	A	-	C	B	A	C	D	D	D	B	B	A	A	A	-	D	D	B	C	B	C	B
Acetic Acid (20%)	-	B	A	-	-	A	A	-	C	-	-	A	B	-	A	A	-	D	-	-	A	A	-	A	-	A	C	-	C	-	-	B
Acetic Acid (80%)	-	B	A	-	-	A	A	-	C	-	-	A	D	-	A	B	-	D	-	-	B	-	-	A	-	A	C	-	D	-	-	B
Acetic Acid	-	B	A	B	B	A	A	C	C	D	C	B	A	B	A	A	D	D	C	B	A	A	A	A	-	C	C	-	C	B	C	A
Acetic Anhydride	B	A	A	B	B	A	A	C	D	B	D	D	D	D	A	D	D	D	D	A	A	A	A	A	-	D	A	C	B	B	C	A
Acetone[6]	A	A	A	B	A	A	A	A	A	A	A	D	D	D	A	D	B	A	D	C	B	A	A	A	A	D	D	B	C	A	D	B
Acetyl Chloride	-	C	A	-	-	-	-	D	-	-	-	-	-	-	A	-	-	-	-	-	-	A	-	-	-	A	-	-	-	-	A	A
Acetylene[2]	A	A	A	A	A	B	-	B	-	A	A	-	B	-	-	-	A	A	-	-	D	A	A	A	-	A	A	C	B	A	C	A
Acrylonitrile	A	A	C	-	B	B	B	A	-	C	-	-	-	-	-	-	B	-	D	-	B	A	A	A	-	C	D	-	D	D	-	A
Alcohols																																
Amyl	A	A	A	-	C	A	A	A	B	C	C	A	A	B	A	C	A	A	B	B	B	A	A	A	-	A	A	D	A	A	C	A
Benzyl	-	A	A	-	B	A	A	A	C	-	-	-	D	B	-	A	A	A	D	D	A	-	A	A	-	A	D	-	B	B	D	A
Butyl	A	A	A	-	B	B	A	B	C	C	C	A	A	B	A	A	A	A	-	B	B	A	A	A	-	A	A	D	A	A	A	A
Diacetone[2]	-	A	A	-	A	A	A	A	C	-	A	-	D	-	-	A	A	A	-	-	D	-	A	A	-	D	D	-	D	A	D	A
Ethyl	-	A	A	A	B	A	A	A	C	A	A	-	A	C	-	A	B	A	B	B	A	-	A	A	A	A	A	B	A	B	A	A
Hexyl	-	A	A	-	A	A	A	A	C	-	A	-	-	-	-	A	A	A	-	-	A	-	A	A	-	A	A	D	B	A	A	A
Isobutyl	-	A	A	-	B	A	A	A	C	-	A	-	-	-	-	A	A	A	B	-	A	-	A	A	-	A	C	B	A	A	A	A
Isopropyl	-	A	A	-	B	A	A	A	C	C	A	-	-	-	-	A	A	A	-	-	A	-	A	A	-	A	C	C	B	A	A	A
Methyl[6]	-	A	A	A	B	A	A	A	C	A	A	-	B	-	A	A	C	A	D	B	A	-	A	A	A	C	B	-	A	A	A	A
Octyl	-	A	A	-	A	A	A	A	C	-	A	-	-	-	-	A	A	A	-	-	-	-	A	A	-	A	B	-	B	A	C	A
Propyl	-	A	A	-	A	A	A	A	-	-	A	B	A	-	A	A	A	A	-	-	A	-	A	A	-	A	A	B	A	A	A	A
Aluminum Chloride (20%)	-	D	C	D	B	A	A	D	-	D	A	-	A	B	-	A	C	A	-	B	A	A	A	A	-	A	A	-	A	A	A	A
Aluminum Chloride	C	D	C	-	D	C	A	C	-	D	B	A	A	A	A	A	-	D	-	-	A	A	A	A	-	A	A	C	A	-	-	A
Aluminum Fluoride	-	D	C	D	-	D	B	-	-	-	A	A	A	-	A	A	C	D	-	B	A	-	A	-	-	A	A	C	A	-	C	A
Aluminum Hydroxide[6]	-	A	A	A	A	-	-	A	-	D	A	-	A	-	A	A	B	A	-	-	A	-	A	A	A	A	A	-	A	-	A	A
Alum Potassium Sulfate (Alum), (10%)	-	A	-	-	A	-	B	-	-	D	A	-	A	-	A	-	-	A	-	A	-	-	A	A	-	A	-	-	A	-	A	A
Alum Potassium Sulfate (Alum), (100%)	-	D	A	B	B	-	B	C	-	-	A	-	A	B	A	A	C	D	-	B	A	-	A	A	-	A	A	-	A	-	A	A
Aluminum Sulfate	-	C	C	A	A	A	A	C	C	D	A	A	A	B	A	A	C	A	-	B	A	A	A	A	-	A	A	-	A	A	A	A
Amines	A	A	A	-	A	B	A	B	-	A	B	-	C	A	A	B	D	A	-	-	-	-	A	A	-	D	D	C	B	B	C	A
Ammonia (10%)	-	-	A	-	-	A	A	-	-	-	-	D	A	-	A	A	-	A	-	-	A	A	-	A	-	A	D	-	A	-	-	B
Ammonia, Anhydrous	A	B	A	A	B	B	A	D	-	D	B	D	A	B	A	A	D	A	-	B	A	B	C	A	-	D	B	B	A	A	D	A
Ammonia, Liquids	-	A	A	A	D	-	B	D	-	A	A	-	A	B	A	A	D	-	-	D	A	-	A	A	-	D	B	B	A	A	D	A
Ammonia, Nitrate	-	A	A	A	C	-	-	D	-	-	A	-	B	B	-	A	C	-	-	-	A	-	A	A	-	-	A	-	C	-	-	A
Ammonium Bifluoride	-	C	A	-	D	-	B	-	-	-	-	-	A	-	-	A	D	-	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Ammonium Carbonate	B	A	A	A	C	A	B	B	-	C	B	-	A	B	A	A	D	A	-	-	A	-	A	A	-	B	D	C	A	A	-	A
Ammonium Casenite	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	A	D	-	-	-	-	-	-	-	-	-	-	-	A	-	-	A
Ammonium Chloride	C	A	C	A	C	D	A	D	C	D	D	A	A	B	A	A	B	A	-	B	A	A	A	A	-	A	A	C	A	A	A	A
Ammonium Hydroxide	A	A	A	A	C	A	A	D	D	A	C	-	A	B	A	A	D	A	B	B	A	A	A	A	-	B	B	B	A	A	C	A
Ammonium Nitrate	A	A	A	A	B	A	A	D	D	A	D	-	A	B	A	A	C	D	-	B	A	A	A	A	-	D	A	C	A	A	A	A
Ammonium Oxalate	-	A	A	A	-	-	A	-	-	-	A	-	-	-	-	-	B	-	-	-	-	-	A	-	-	-	A	-	A	-	-	A
Ammonium Persulfate	-	A	A	A	C	C	A	A	-	D	A	D	A	-	A	A	D	D	-	-	A	-	A	A	-	C	A	-	A	A	A	A
Ammonium Phosphate, Dibasic	B	A	A	A	B	A	A	C	-	-	D	-	A	-	A	A	B	A	-	B	A	-	A	A	-	A	A	B	A	A	A	A
Ammonium Phosphate, Monobasic	-	A	A	A	B	A	A	D	-	-	A	-	A	A	A	A	B	A	-	B	A	-	A	A	-	A	A	B	A	A	A	A
Ammonium Phosphate, Tribasic	B	A	A	A	B	A	A	C	-	C	D	-	A	-	A	A	B	A	-	B	A	-	A	A	-	A	A	B	A	A	A	A
Ammonium Sulfate	C	D	B	A	B	A	A	B	C	C	C	A	A	D	A	A	B	D	-	B	A	A	A	A	-	D	A	B	A	A	A	A
Ammonium Thio-Sulfate	-	-	A	-	-	A	-	-	-	D	A	-	-	-	-	-	B	-	-	-	-	-	A	A	-	-	A	-	A	-	-	A
Amyl-Acetate	B	A	A	C	B	A	A	C	-	-	C	C	D	D	A	D	A	B	-	D	D	A	A	A	-	D	D	D	D	A	D	A
Amyl Alcohol	-	A	A	-	B	A	A	A	-	-	A	A	A	B	A	C	A	A	-	B	A	-	A	A	-	B	B	D	A	A	C	A
Amyl Chloride	-	C	B	-	D	-	A	A	-	-	A	A	D	C	A	D	A	C	-	D	D	-	A	A	-	A	D	-	D	D	D	A
Aniline	B	A	A	A	C	A	B	C	-	-	C	C	D	D	A	D	D	C	D	C	B	A	A	A	-	C	D	C	D	B	D	A
Anti-Freeze	-	A	A	-	A	-	A	B	B	B	C	-	A	B	A	A	A	A	B	B	A	A	A	A	A	A	A	C	A	A	A	A
Antimony Trichloride	-	D	D	-	D	C	A	-	-	-	-	-	A	A	A	-	-	D	-	A	-	-	-	A	-	A	-	-	C	-	A	A
Aqua Regia (80% HCl, 20% HNO)	-	D	D	-	D	A	D	D	-	-	-	C	D	D	A	D	D	D	-	D	C	-	-	D	-	C	D	C	D	D	D	D

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Arochlor 1248	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	D	-	-	-	-	-	-	A	-	-	A	D	-	D	B	D	A
Aromatic Hydrocarbons	-	-	A	-	A	-	-	A	-	A	A	-	D	-	-	D	A	-	-	C	-	-	A	-	-	A	D	-	D	D	D	A
Arsenic Acid	B	A	A	-	D	-	-	D	B	D	D	A	A	B	A	A	D	A	-	B	A	-	A	A	-	A	A	-	A	-	C	A
Asphalt	-	B	A	-	C	-	-	A	-	C	-	-	A	-	-	-	A	A	-	-	A	A	-	A	A	A	B	C	B	D	D	A
Barium Carbonate	B	A	A	A	B	A	A	B	-	B	B	-	A	A	A	A	A	A	-	B	A	-	A	A	A	A	A	-	A	-	A	A
Barium Chloride	C	D	A	A	D	A	A	B	-	-	C	A	A	B	A	A	A	B	-	B	A	A	A	A	-	A	A	B	A	A	A	A
Barium Cyanide	-	-	A	-	-	-	-	C	-	-	A	-	-	-	-	-	B	-	-	B	-	-	A	-	-	A	C	-	A	A	-	A
Barium Hydroxide	B	C	A	A	D	B	B	B	-	C	C	A	A	-	A	A	D	A	-	B	A	A	A	A	A	A	A	C	A	A	A	A
Barium Nitrate	-	A	A	-	-	A	-	D	-	A	A	-	B	-	-	A	A	-	-	-	-	-	A	A	-	A	A	-	A	A	-	B
Barium Sulfate	B	A	A	A	D	A	A	C	-	C	C	A	A	-	A	A	A	A	-	B	A	A	A	B	-	A	A	D	A	A	-	B
Barium Sulfide	B	A	A	-	D	B	-	C	-	C	C	-	A	A	A	A	A	A	-	B	A	-	A	A	-	A	A	C	A	A	A	A
Beer[2]	A	A	A	-	A	A	A	A	B	D	D	A	A	-	A	A	B	D	B	B	D	-	A	A	-	A	D	C	A	A	A	A
Beet Sugar Liquids	A	A	A	-	A	-	-	A	B	A	-	-	A	-	A	A	B	A	B	-	A	-	A	A	-	A	A	-	B	A	A	A
Benzaldehyde[3]	A	A	A	-	B	A	A	A	-	B	A	C	D	D	A	D	A	C	D	D	D	A	A	A	-	D	D	B	D	A	D	A
Benzene[2]	B	A	A	A	B	A	B	B	A	B	C	B	D	C	A	D	A	A	D	D	D	A	A	A	A	A	D	-	D	D	D	A
Benzoic Acid[2]	B	A	A	A	B	A	A	B	-	D	-	A	A	B	A	A	B	D	-	B	D	-	A	B	-	A	D	-	D	D	D	A
Benzol	-	A	A	-	B	A	A	B	A	-	-	-	D	-	A	D	A	A	-	-	A	-	A	A	A	D	D	-	D	-	-	A
Borax (Sodium Borate)	-	A	A	A	C	B	A	A	B	A	C	A	A	A	A	A	A	A	-	B	A	A	A	A	A	A	B	C	A	A	C	A
Boric Acid	B	A	A	A	B	A	A	B	C	D	-	A	A	B	A	A	A	A	-	B	A	-	A	A	A	A	A	-	A	A	A	A
Brewery Slop	-	-	A	-	-	-	-	A	-	A	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	A	-	-	A
Bromine[2] (Wet)	D	D	D	D	D	A	A	C	-	D	D	A	B	B	A	D	D	D	D	D	D	D	D	A	D	A	D	D	D	D	D	C
Butadiene	A	A	A	-	A	-	-	C	A	C	C	A	A	-	A	-	A	A	-	-	-	B	A	A	-	A	A	-	B	A	-	A
Butane[2 1]	A	A	A	-	A	-	-	A	A	C	C	A	A	C	A	D	A	A	B	C	D	A	A	A	-	A	A	D	B	D	D	A
Butanol	-	A	A	-	A	-	A	A	-	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Butter	-	B	A	-	A	-	-	D	-	D	-	-	-	B	-	B	A	-	B	-	-	-	A	A	-	A	A	-	B	A	D	A
Buttermilk	A	A	A	A	A	-	-	D	-	D	-	-	-	B	A	A	A	A	B	-	-	-	A	A	-	A	A	-	A	-	D	A
Butylene	A	B	A	-	A	-	-	A	A	A	A	-	B	-	A	-	A	-	-	-	-	A	A	A	-	A	B	-	-	D	D	A
Butyl Acetate[1]	-	-	C	-	A	-	A	A	-	-	A	C	D	D	A	D	A	-	-	C	D	A	A	A	-	D	B	D	D	B	D	A
Butyric Acid[1]	B	B	A	A	B	A	A	C	-	D	-	A	B	-	A	A	C	D	D	-	A	-	A	D	-	D	D	-	D	B	-	A
Calcium Bisulfate	C	D	A	-	D	-	-	D	D	D	-	-	A	A	A	-	-	A	-	-	-	-	-	-	-	A	A	C	C	-	A	A
Calcium Bisulfide	-	-	B	-	C	A	A	C	-	-	-	-	A	-	A	A	D	A	-	B	A	-	A	A	-	A	A	-	A	D	-	A
Calcium Bisulfite	-	B	A	-	C	A	A	C	-	-	-	A	A	-	A	A	-	A	-	-	A	-	-	A	-	A	A	-	A	-	A	-
Calcium Carbonate	B	A	A	A	C	A	A	C	-	D	-	-	A	A	A	A	A	A	-	B	A	-	A	A	-	A	A	-	A	-	A	A
Calcium Chlorate	-	B	A	-	-	B	B	C	-	-	-	-	A	A	A	-	-	A	-	A	-	-	A	-	-	A	-	-	A	-	A	A
Calcium Chloride	C	A	D	C	C	A	A	B	-	C	-	A	A	A	A	A	D	A	B	B	A	A	A	A	B	A	A	B	D	A	A	A
Calcium Hydroxide	B	A	A	-	C	A	A	B	-	-	-	-	A	A	A	A	B	A	-	B	A	-	A	A	A	A	A	C	A	A	A	A
Calcium Hypochlorite	D	D	C	C	C	A	B	D	-	D	-	A	D	-	A	A	D	D	-	B	A	-	A	A	-	A	B	C	D	A	C	A
Calcium Sulfate	B	A	A	A	B	A	B	B	-	-	-	A	A	A	A	A	A	A	C	B	A	A	A	A	-	A	A	-	D	-	C	A
Calgon	-	A	A	-	-	-	-	C	-	D	-	-	-	-	-	A	B	-	-	-	A	-	A	A	-	A	A	-	A	-	-	A
Cane Juice[2]	-	A	A	-	B	-	-	B	C	A	-	-	A	-	-	-	A	A	-	-	D	-	A	A	-	-	A	-	A	-	A	A
Carbolic Acid (See Phenol)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbon Bisulfide[2]	B	A	A	A	A	-	-	C	-	B	-	-	D	D	-	-	A	A	-	-	D	-	A	A	A	A	D	-	D	D	D	A
Carbon Dioxide (Wet)	-	A	A	-	C	-	A	C	C	C	-	-	-	-	A	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-	-	-
Carbon Disulfide[2]	-	B	A	-	C	-	-	C	C	B	C	-	D	C	A	D	A	A	-	D	D	A	A	B	-	A	D	-	D	D	D	A
Carbon Monoxide	-	A	A	-	A	-	-	-	-	-	-	-	A	-	-	B	A	A	-	B	A	-	A	A	-	A	A	B	B	A	C	A
Carbon Tetrachloride[2 1]	B	B	B	A	C	A	A	C	A	C	D	A	C	C	A	D	A	A	D	D	D	C	A	A	A	A	C	C	D	-	D	C
Carbonated Water	B	A	A	A	A	-	-	B	-	D	-	-	A	-	-	A	A	A	-	-	A	-	A	A	-	A	A	-	A	A	-	A
Carbonic Acid	B	A	B	A	A	-	A	B	-	D	-	A	A	-	A	A	A	A	-	B	A	-	A	A	-	A	B	B	A	A	A	A
Catsup	-	A	A	A	D	-	-	C	-	D	-	-	A	-	-	A	B	A	B	-	A	-	A	A	-	A	A	-	C	-	-	A
Chloracetic Acid[2]	D	D	D	D	C	A	A	D	-	D	-	D	A	D	A	-	D	D	-	D	D	-	A	A	-	D	D	-	D	B	D	B
Chloric Acid	-	D	D	-	-	-	-	-	-	-	-	-	D	-	A	-	-	-	-	-	-	-	-	-	-	-	D	-	D	-	-	D
Chlorinated Glue	-	A	A	-	D	-	-	C	-	D	-	-	-	-	-	C	-	C	D	-	-	-	-	A	-	A	C	-	D	B	D	A
Chlorine, Anhydrous Liquid	-	D	D	D	D	D	A	D	-	C	-	-	D	B	A	A	D	D	-	D	D	C	A	D	-	A	D	-	D	B	D	B
Chlorine (Dry)	B	A	A	-	D	D	A	A	B	A	-	-	-	-	A	-	-	-	-	-	-	C	A	A	-	D	-	-	D	-	D	D
Chlorine Water	D	-	D	-	D	A	B	D	D	D	-	A	A	-	A	C	-	D	-	-	D	C	C	A	-	A	D	C	D	-	-	-
Chlorobenzene (Mono)	A	A	A	-	B	-	A	B	-	B	C	A	D	D	A	D	A	A	D	D	D	A	A	A	-	A	D	-	D	D	D	A

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Chloroform	A	A	A	A	D	A	A	B	-	D	C	C	D	C	A	D	A	C	D	D	D	C	A	A	A	A	D	D	D	D	D	A
Chlorosulfonic Acid[1]	D	D	-	D	D	A	B	D	-	-	D	D	C	C	A	D	D	D	-	D	D	D	-	C	-	D	D	D	D	D	D	C
Chlorox (Bleach)	-	A	A	-	C	-	A	A	-	D	C	-	A	B	A	A	D	D	B	-	D	C	A	A	-	A	C	-	B	B	D	A
Chocolate Syrup	-	A	A	-	A	-	-	-	-	D	-	-	-	-	-	A	A	A	-	-	A	-	-	A	-	A	A	-	A	-	D	A
Chromic Acid (5%)	-	A	A	B	C	A	A	D	D	D	-	-	A	B	-	C	D	D	B	B	A	A	D	C	-	A	D	C	D	A	B	B
Chromic Acid (10%)	-	B	-	-	-	A	A	-	D	-	-	A	A	-	A	A	-	D	-	-	A	-	-	A	-	A	D	-	D	-	-	C
Chromic Acid (30%)	-	B	-	-	-	A	A	-	D	-	-	B	A	-	A	D	-	D	-	-	A	-	-	A	-	A	D	-	D	-	-	D
Chromic Acid (50%)	C	B	B	-	C	A	A	D	D	D	-	C	B	B	A	D	D	D	C	C	B	B	D	A	-	A	D	-	D	A	D	C
Cider	-	A	A	A	B	-	-	A	-	D	-	-	A	-	-	A	B	-	-	B	-	-	A	A	-	A	A	-	A	-	-	A
Citric Acid	-	A	A	A	C	A	A	D	C	D	-	A	A	-	A	A	B	C	C	B	B	-	A	A	B	A	D	C	A	A	A	A
Citric Oils	-	A	A	-	C	-	-	B	-	-	-	-	-	-	-	A	B	-	-	-	A	-	A	A	-	A	A	C	D	-	-	A
Coffee	A	A	A	A	A	-	-	B	-	C	-	-	-	-	A	A	A	A	-	-	A	-	A	A	-	A	A	-	A	-	A	A
Copper Chloride	C	D	D	B	D	A	A	D	-	D	-	A	A	B	A	A	B	D	-	B	A	A	-	A	-	A	A	-	A	A	A	A
Copper Cyanide	-	A	A	A	D	A	A	C	-	D	-	A	A	-	A	A	B	A	-	B	A	A	A	A	-	B	B	-	A	A	A	C
Copper Fluoborate	-	D	D	-	D	-	B	D	-	D	-	-	A	-	A	-	B	-	-	A	-	-	A	-	-	A	B	-	A	-	A	A
Copper Nitrate	B	A	A	B	D	A	A	D	-	-	-	A	A	-	A	A	B	D	-	B	A	-	A	A	-	A	A	-	A	-	-	A
Copper Sulfate (5% Solution)	-	A	A	A	D	A	A	D	D	D	-	-	A	-	A	A	B	D	-	B	A	A	A	A	-	A	A	C	A	-	C	A
Copper Sulfate	B	B	-	-	-	A	A	C	D	-	-	A	A	-	A	A	-	C	-	-	A	-	-	A	-	B	B	-	A	A	-	A
Cream	-	A	A	-	A	-	-	C	-	D	-	-	-	-	-	A	A	A	-	-	A	-	A	A	-	A	A	-	C	-	-	A
Cresols[2]	-	A	A	-	B	-	-	D	C	-	-	-	D	D	-	-	D	-	D	D	C	A	A	A	-	D	D	D	D	D	D	A
Cresylic Acid	B	A	A	-	C	A	B	C	-	-	-	B	B	D	A	-	D	D	-	C	-	-	A	A	-	A	D	-	D	D	D	A
Cyclohexane	-	A	-	-	A	A	-	A	-	-	A	-	-	D	-	D	A	-	-	-	D	A	A	A	-	A	A	D	D	D	D	A
Cyanic Acid	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D	-	-	-	-	-	-	-	-	-	C	-	D	-	-	A
Detergents	-	A	A	-	A	-	-	A	-	-	A	-	A	-	-	A	B	A	B	B	A	A	A	A	-	A	A	-	B	A	C	A
Dichlorethane	-	A	A	-	-	-	A	-	-	-	-	-	D	D	A	-	-	A	-	D	-	-	-	-	-	B	-	-	D	-	D	A
Diesel Fuel	A	A	A	-	A	-	-	A	-	A	A	-	-	-	-	D	A	-	-	-	D	A	A	A	-	A	A	-	D	D	D	A
Diethylamine	A	A	-	-	A	-	-	A	-	-	-	-	D	-	A	B	D	-	-	-	C	-	A	A	-	D	B	-	B	B	C	A
Diethylene Glycol	-	A	-	-	-	-	-	A	-	-	-	-	-	-	-	A	A	A	B	B	-	-	A	A	-	A	A	C	A	A	A	A
Diphenyl Oxide	-	A	-	-	-	-	-	A	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	D	-	D	D	D	A
Dyes	-	A	A	-	B	-	-	C	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-	-	-	A	-	-	C	-	-	A
Epsom Salts (Magnesium Sulfate)	B	A	A	A	A	A	B	B	-	-	-	-	A	-	-	A	A	-	-	-	A	-	A	A	-	A	A	-	A	-	C	A
Ethane	A	A	-	-	A	-	-	A	-	-	-	-	-	-	-	D	A	-	-	-	-	-	A	A	-	A	A	-	B	D	D	A
Ethanolamine	-	A	A	-	-	-	-	-	-	-	C	-	-	-	-	-	D	-	-	-	-	A	A	A	-	D	B	C	B	-	C	A
Ether[3]	A	A	A	A	A	-	B	B	A	-	B	-	D	C	-	D	A	C	-	-	-	A	A	A	A	C	D	-	D	C	D	A
Ethyl Acetate[2]	-	A	A	-	B	-	B	B	-	-	C	D	D	D	A	D	A	A	D	C	C	A	A	A	-	D	D	C	D	B	D	A
Ethyl Chloride	-	A	A	A	B	A	B	B	-	C	D	A	D	D	A	D	A	A	-	D	D	A	A	A	-	A	D	D	C	A	A	A
Ethyl Sulfate	-	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	B	-	-	-	-	-	A	A	-	A	A	-	-	-	-	A
Ethylene Chloride[2]	-	A	A	-	C	B	B	A	-	C	C	-	D	-	A	D	A	-	D	-	D	A	A	A	-	A	D	D	D	C	D	A
Ethylene Dichloride	-	A	A	-	D	A	B	C	-	-	C	-	D	D	A	D	A	A	-	D	A	A	C	A	-	A	D	D	D	C	D	A
Ethylene Glycol[4]	-	A	A	-	A	-	A	B	B	B	C	A	A	B	A	A	A	A	B	B	A	A	A	A	A	A	A	C	A	A	A	A
Ethylene Oxide	-	-	A	-	A	-	-	A	-	-	-	-	D	-	A	A	A	A	-	-	-	-	A	A	-	D	D	D	D	C	D	A
Fatty Acids	-	A	A	-	B	A	A	C	-	D	-	A	A	B	A	B	A	A	-	B	A	-	A	A	-	A	C	C	B	C	C	A
Ferric Chloride	-	D	D	D	D	A	B	D	D	D	-	A	A	B	A	A	B	D	-	B	A	A	A	A	-	A	D	C	B	A	A	A
Ferric Nitrate	-	A	A	A	D	A	A	D	-	-	-	A	A	-	A	A	B	D	-	B	A	A	A	A	-	A	A	D	A	A	A	A
Ferric Sulfate	-	A	C	A	D	A	A	D	D	D	-	A	A	B	A	A	B	A	C	-	A	A	C	A	-	A	B	C	A	-	A	A
Ferrous Chloride	-	D	D	-	D	A	B	C	-	D	-	A	A	B	A	A	B	D	-	B	A	A	A	A	-	A	B	C	A	-	A	A
Ferrous Sulfate	B	A	C	-	D	A	B	C	-	D	D	A	A	B	A	A	B	D	-	B	A	A	A	A	-	A	B	-	A	-	A	A
Fluoboric Acid	-	D	B	-	-	D	A	-	-	D	-	A	A	B	A	B	B	C	-	B	A	-	A	D	-	A	B	-	A	-	-	A
Fluorine	D	D	D	-	D	D	A	D	-	D	D	-	C	-	C	-	-	D	-	C	-	-	D	-	-	-	-	-	-	-	-	D
Fluosilicic Acid	-	-	B	-	D	D	B	-	-	D	-	A	A	B	A	A	B	D	-	B	A	-	A	D	-	B	A	-	A	-	-	C
Formaldehyde (40%)	-	-	A	-	-	A	A	-	-	-	-	B	B	-	A	A	-	D	-	-	A	A	-	A	-	D	B	B	A	-	-	A
Formaldehyde	A	A	A	-	A	A	B	A	B	D	A	-	A	B	A	D	A	A	-	B	A	A	A	A	-	D	C	B	D	B	C	A
Formic Acid[6]	C	A	B	B	D	C	A	C	C	D	D	A	D	B	A	A	D	D	-	B	A	A	A	A	B	B	D	C	D	A	C	B
Freon 111	A	-	A	-	B	-	-	B	-	C	B	-	B	D	A	D	A	A	D	C	-	A	A	A	A	B	C	D	D	D	D	A
Freon 12 (Wet)[2]	-	-	D	-	B	-	-	B	-	-	-	-	B	D	A	D	A	A	B	C	A	A	A	A	A	A	A	D	B	B	D	A
Freon 22	-	-	A	-	B	-	-	B	-	-	-	-	D	D	-	B	A	A	-	-	-	A	A	A	A	D	D	D	A	A	A	A

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Freon 113	-	-	A	-	B	-	-	B	-	-	-	-	C	D	-	-	A	A	-	-	-	A	A	A	A	C	A	D	A	-	D	A
Freon T.F.[4]	-	-	A	-	B	-	-	B	-	-	-	-	B	D	-	D	A	A	-	-	D	A	A	A	A	B	A	D	A	D	D	A
Fruit Juice	A	A	A	A	B	-	-	B	-	D	D	-	A	-	D	A	B	A	-	B	A	-	A	A	A	A	A	-	A	-	-	A
Fuel Oils	A	A	A	-	A	A	A	B	-	C	B	A	A	-	A	A	A	A	-	D	B	A	A	A	-	A	A	C	B	D	D	A
Furan Resin	-	A	A	-	A	-	-	A	-	A	A	-	-	-	A	-	A	-	-	-	-	A	-	A	-	A	D	-	D	-	D	A
Furfural[1]	A	A	A	-	A	-	B	A	-	-	A	D	D	-	A	D	B	A	D	D	D	A	A	A	-	D	D	D	D	B	D	A
Gallic Acid	B	A	A	-	A	-	A	A	-	D	D	-	A	A	A	-	-	A	-	-	-	-	-	-	-	B	A	-	-	-	-	-
Gasoline[1 4]	A	A	A	A	A	D	A	A	-	A	A	A	C	-	A	D	A	A	D	D	C	A	A	A	A	A	A	D	D	C	D	A
Gelatin	A	A	A	A	A	-	A	A	C	D	D	-	A	-	A	A	A	A	-	-	A	-	A	A	-	A	A	-	A	A	A	A
Glucose	A	-	A	-	A	-	-	A	A	B	B	-	A	B	A	B	A	A	B	B	A	-	A	A	-	A	A	B	A	A	A	A
Glue P.V.A.[1]	B	B	A	-	B	A	-	A	-	-	A	-	A	B	A	-	A	A	-	-	-	-	A	A	-	A	A	-	A	-	-	A
Glycerine	A	A	A	A	A	A	A	A	B	B	B	A	A	B	A	A	A	A	C	-	A	-	A	A	-	A	A	B	A	A	A	A
Glycolic Acid	-	-	-	-	-	-	A	-	-	-	-	-	-	A	-	A	C	-	-	B	A	A	A	-	-	A	A	-	A	-	-	A
Gold Monocyanide	-	-	A	-	-	-	-	A	-	D	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	A	-	-	A
Grape Juice	-	A	A	-	B	-	-	B	-	D	-	-	A	-	-	A	B	-	B	B	-	-	A	A	-	A	A	-	A	-	-	A
Grease[4]	A	A	A	-	A	-	-	B	-	A	A	-	-	-	A	-	A	A	-	-	-	-	A	A	-	A	A	-	D	-	-	A
Heptane[1]	A	-	A	-	A	-	A	A	-	-	B	A	A	-	A	D	A	A	C	D	D	A	A	A	-	A	A	-	B	D	-	A
Hexane[1]	A	A	A	-	A	-	A	B	-	-	B	A	C	-	A	D	A	A	D	-	C	A	A	A	-	A	A	B	B	D	D	A
Honey	-	A	A	-	A	-	-	A	-	A	-	-	A	-	-	A	A	A	B	-	A	-	A	A	-	A	A	-	A	A	-	A
Hydraulic Oils (Petroleum)[1]	A	A	A	-	A	-	-	B	-	A	A	-	-	-	A	-	A	A	-	-	D	-	A	A	-	A	A	-	B	D	D	A
Hydraulic Oils (Synthetic)[1]	-	A	A	-	A	-	-	A	-	A	-	-	-	-	-	-	A	A	-	-	D	-	A	A	-	A	C	D	-	-	-	A
Hydrazine	-	A	A	-	-	-	-	-	-	C	-	-	-	-	-	-	D	-	-	-	-	-	A	-	-	A	B	D	B	A	C	A
Hydrobromic Acid (20%)	-	-	D	-	-	A	A	-	-	-	-	A	A	-	A	A	-	D	-	-	A	-	-	B	-	A	D	-	C	-	-	B
Hydrobromic Acid4	D	D	D	D	D	A	A	D	-	D	D	A	A	B	A	C	D	D	-	B	B	-	A	A	-	A	D	D	D	A	A	A
Hydrochloric Acid (Dry gas)	D	C	A	-	D	-	A	-	-	-	D	-	A	-	A	-	-	-	-	-	-	-	A	-	-	-	-	-	-	A	-	A
Hydrochloric Acid (20%)[4]	-	D	D	D	D	C	B	D	-	D	-	A	A	B	A	A	D	D	B	A	A	D	A	A	D	A	C	-	C	A	C	A
Hydrochloric Acid (37%)[4]	-	D	D	D	D	C	B	D	-	D	-	A	A	B	A	A	D	D	C	A	A	D	A	C	D	A	C	C	C	C	D	A
Hydrochloric Acid (100%)	-	D	D	-	D	D	C	D	-	D	-	-	A	A	A	-	-	D	-	A	-	-	A	C	-	C	D	-	C	-	A	A
Hydrocyanic Acid	A	A	A	C	A	A	A	D	D	-	C	-	A	B	A	A	B	A	-	B	A	-	A	A	-	A	C	-	B	-	A	A
Hydrocyanic Acid (Gas 10%)	-	D	D	-	-	-	-	-	-	-	-	-	A	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	C	A	C	A
Hydrofluoric Acid (20%)[1]	-	D	D	D	D	D	B	D	-	D	-	-	D	B	A	A	D	D	-	C	A	C	B	C	D	A	D	-	C	A	C	B
Hydrofluoric Acid (75%)[1 2]	-	C	D	-	D	D	C	D	-	D	-	A	C	B	A	D	D	D	-	C	B	C	D	D	D	A	D	D	D	C	C	C
Hydrofluoric Acid (100%)	D	D	D	-	D	D	B	D	-	D	D	-	C	D	A	-	-	-	-	D	-	C	D	D	-	-	D	-	D	-	D	A
Hydrofluosilicic Acid (20%)	-	D	D	-	D	D	B	A	-	D	-	-	D	-	A	B	D	D	-	-	A	-	A	D	-	A	B	-	B	A	A	C
Hydrofluosilicic Acid	-	D	D	-	C	-	C	D	-	-	-	-	-	C	A	-	-	-	-	-	-	-	A	-	-	-	-	D	A	-	-	-
Hydrogen Gas	A	A	A	-	A	-	-	A	-	B	B	A	A	-	A	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A
Hydrogen Peroxide (10%)	-	C	C	-	A	C	A	D	D	D	-	-	A	A	A	-	-	D	-	A	-	B	A	A	-	-	A	-	D	-	C	D
Hydrogen Peroxide (30%)	-	-	B	-	-	B	A	-	D	-	-	-	A	-	A	-	-	D	-	-	A	C	-	-	-	A	D	-	C	-	-	B
Hydrogen Peroxide	-	A	B	A	A	B	A	D	D	D	D	C	A	C	A	B	D	D	-	B	A	C	-	A	A	A	D	C	D	C	C	A
Hydrogen Sulfide, Aqueous Solution	-	D	A	C	C	A	A	D	C	D	-	A	A	B	A	A	D	D	-	B	A	A	A	A	A	D	C	-	B	A	D	A
Hydrogen Sulfide (Dry)	A	C	A	-	D	-	A	D	C	B	B	-	A	-	A	-	-	D	-	-	-	A	-	A	-	D	-	-	-	-	A	A
Hydroxyacetic Acid (70%)	-	-	-	-	D	B	-	-	-	-	-	-	A	-	-	-	D	-	-	-	-	-	A	A	-	A	A	-	A	A	-	A
Ink	A	A	A	-	C	-	-	C	-	D	D	-	-	-	-	B	A	A	-	B	-	-	A	A	A	A	A	-	A	-	-	A
Iodine	-	D	D	D	D	A	B	D	-	D	-	-	D	B	A	A	C	D	D	D	D	-	D	A	-	A	B	-	D	B	D	A
Iodine (In Alcohol)	-	-	B	-	-	D	A	-	-	-	-	-	D	-	A	C	-	D	-	-	B	-	-	A	-	A	D	-	D	-	-	-
Iodoform	B	C	A	-	A	-	-	C	-	C	B	-	-	-	A	-	-	A	-	-	-	-	-	-	-	A	-	-	-	-	-	-
Isotane[2]	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	D	A	-	-	-	D	-	-	A	-	A	A	-	-	-	D	A
Isopropyl Acetate	-	-	B	-	C	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	D	D	-	D	B	D	A
Isopropyl Ether[2]	A	-	A	-	A	-	-	A	-	-	A	-	-	-	A	D	A	-	-	-	D	-	A	A	-	D	B	-	D	D	D	-
Jet Fuel (JP#, JP4, JP5)	A	A	A	-	A	-	-	A	-	A	A	A	A	-	A	D	A	A	-	-	D	A	A	A	-	A	A	D	D	D	D	A
Kerosene[2]	A	A	A	A	A	A	A	A	A	A	B	A	A	D	A	D	A	A	B	D	D	A	A	A	A	A	A	D	D	A	D	A
Ketones	A	A	A	-	B	A	A	A	-	A	A	D	D	D	A	D	B	A	-	D	D	A	C	A	-	D	D	-	D	D	C	C
Lacquers	A	A	A	-	A	-	-	A	C	C	C	-	-	D	-	C	A	A	-	-	A	-	A	A	-	D	D	-	D	-	D	A
Lacquer Thinners	-	-	A	-	-	A	A	-	C	-	-	-	C	-	A	D	-	A	-	-	B	-	-	A	-	-	D	-	D	A	-	-
Lactic Acid	A	A	B	C	C	A	A	D	-	D	D	C	A	B	A	A	B	C	-	B	A	A	A	A	-	B	B	-	A	B	A	A
Lard	B	A	A	A	A	-	-	A	-	A	C	-	A	-	-	-	A	A	C	-	A	-	A	A	-	A	A	C	B	-	D	A

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Latex	-	A	A	-	A	-	-	A	-	-	-	-	-	-	-	A	A	A	-	B	-	-	-	A	-	A	A	-	C	A	-	A
Lead Acetate	B	A	A	-	D	A	A	C	-	-	D	-	A	B	A	A	A	A	-	B	A	-	A	A	-	D	B	-	D	A	A	A
Lead Sulfamate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	A	-	-	-	-	A	B	C	A	D	C	A
Ligroin[3]	-	-	A	-	-	-	-	A	-	-	-	-	-	-	-	D	A	-	-	-	D	-	-	A	-	A	A	-	B	A	D	A
Lime	-	A	A	-	C	A	-	A	-	A	-	-	A	-	-	A	D	-	C	-	-	-	A	A	-	A	A	C	B	D	-	A
Lubricants	-	A	A	-	A	A	A	B	-	-	-	-	A	-	A	-	A	A	B	-	A	A	A	A	-	A	A	C	D	-	D	A
Magnesium Carbonate	-	A	A	A	-	-	B	-	-	-	-	-	A	-	-	A	A	-	-	B	A	-	-	A	-	-	A	-	A	A	-	A
Magnesium Chloride	B	B	B	A	D	A	A	B	C	D	C	-	A	B	A	A	A	A	-	B	A	A	-	A	-	A	A	-	A	A	A	A
Magnesium Hydroxide	A	A	A	-	D	A	A	C	B	B	B	A	A	-	A	A	A	A	-	B	A	A	A	A	-	A	B	-	B	-	C	A
Magnesium Nitrate	-	A	A	A	-	A	A	-	-	-	-	-	A	-	A	A	A	A	-	B	A	-	-	A	-	A	A	-	A	-	-	A
Magnesium Oxide	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	-	A	-	-	A	-	A	A	-	A
Magnesium Sulfate	B	B	A	-	B	A	B	B	B	C	B	-	A	B	A	A	A	A	-	B	A	A	A	A	-	A	A	-	A	D	C	A
Maleic Acid	C	A	A	A	B	A	A	C	-	-	B	-	A	B	A	A	C	A	-	-	C	-	A	A	-	A	D	-	A	D	D	A
Maleic Anhydride	-	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	A	A	-	A	D	-	D	-	D	A
Malic Acid	B	A	A	-	C	-	A	D	-	-	D	-	A	-	A	-	-	A	-	-	-	-	-	A	-	B	-	-	A	-	A	-
Mash	-	A	A	-	-	-	-	A	-	-	-	-	-	-	-	A	A	-	-	-	-	-	A	A	-	-	A	-	A	-	-	A
Mayonnaise	A	A	A	-	D	-	-	D	-	D	D	-	-	-	A	A	A	A	B	-	A	-	A	A	-	A	A	-	-	-	-	A
Melamine	-	D	D	-	-	-	-	D	-	-	-	-	-	-	-	-	D	-	-	-	-	-	A	A	-	-	C	-	-	-	-	A
Mercuric Chloride (Dilute Solution)	D	D	D	D	D	A	B	D	D	D	D	-	A	A	A	A	A	A	-	B	A	-	A	A	-	A	A	-	A	A	A	A
Mercuric Cyanide	A	A	A	-	D	A	-	D	-	-	D	-	A	-	A	A	A	-	-	B	A	-	A	A	-	-	A	-	-	-	-	A
Mercury	A	A	A	A	C	C	A	D	D	A	A	-	A	-	A	A	A	A	-	B	A	-	A	A	-	A	A	-	A	A	A	A
Methanol (See Alcohols, Methyl)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Methyl Acetate	A	-	A	-	A	-	A	A	-	-	B	-	-	-	A	-	A	-	D	-	-	-	A	A	-	D	D	D	B	B	D	-
Methyl Acrylate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	D	D	-	B	B	D	A
Methyl Acetone	A	-	A	-	A	-	-	A	-	A	A	-	-	-	A	D	A	-	-	-	-	-	-	A	-	D	D	-	D	-	-	C
Methyl Alcohol (10%)	A	-	A	-	C	-	A	C	-	-	B	-	A	-	A	-	-	A	-	-	-	-	-	-	-	-	B	-	-	-	A	A
Methyl Bromide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	D	-	-	A	A	-	A	B	-	D	D	D	B
Methyl Butyl Ketone	-	-	A	-	A	-	-	-	-	-	-	-	-	-	-	D	B	-	-	-	-	-	A	A	-	D	D	C	D	A	D	B
Methyl Cellosolve	-	-	-	-	A	-	-	A	-	-	-	-	-	-	-	C	B	-	-	-	A	-	A	A	-	D	D	-	D	B	D	C
Methyl Chloride	-	A	A	-	D	A	A	A	-	-	-	A	D	-	A	D	A	A	-	D	D	-	A	A	-	A	D	D	D	C	D	A
Methyl Dichloride	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	D	A	-	-	-	-	-	A	A	-	A	D	-	D	D	D	A
Methyl Ethyl Ketone	-	A	A	-	A	A	A	A	-	-	-	D	D	-	A	D	B	A	D	D	A	A	A	A	-	D	D	C	D	A	D	B
Methyl Isobutyl Ketone[2]	-	-	A	-	-	A	A	-	-	-	-	D	D	-	A	D	B	A	D	-	C	A	A	A	-	D	D	C	D	C	D	B
Methyl Isopropyl Ketone	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	D	B	A	-	-	-	-	A	A	-	D	D	B	D	B	D	B
Methyl Methacrylate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	D	D	-	D	D	D	A
Methylamine	A	-	A	-	A	-	-	D	-	B	B	-	-	-	-	B	D	-	-	-	-	-	A	A	-	-	B	-	-	-	-	A
Methylene Chloride	A	A	A	-	A	A	A	A	C	-	B	D	D	-	A	D	A	D	-	D	D	-	A	A	-	D	D	-	D	D	D	A
Milk	A	A	A	A	A	-	-	C	C	D	D	-	A	-	-	A	A	A	B	B	A	-	A	A	A	A	A	B	A	A	A	A
Molasses	A	A	A	A	A	-	-	A	B	A	A	-	A	-	-	B	A	A	-	B	A	-	A	A	A	A	A	-	A	-	-	A
Mustard	A	A	A	A	B	-	-	B	-	C	B	-	A	-	-	B	B	A	B	-	A	-	A	A	-	A	B	C	C	-	-	A
Naptha	A	A	A	A	A	A	A	B	-	B	B	A	A	C	A	D	A	A	C	D	A	A	A	A	-	A	B	D	D	D	D	A
Napthalene	B	A	B	-	B	A	A	C	-	B	A	A	D	-	A	D	A	-	-	D	B	A	A	A	-	B	D	-	D	D	D	A
Nickel Chloride	-	A	B	-	D	A	A	D	-	D	-	A	A	B	A	A	B	A	-	B	A	-	A	A	-	A	A	-	A	A	A	A
Nickel Sulfate	B	A	B	-	D	A	B	C	C	D	D	A	A	A	A	A	B	A	-	B	A	-	A	A	-	A	A	-	A	A	C	A
Nitric Acid (10% Solution)	A	A	A	A	D	A	A	D	-	D	D	A	A	B	A	A	D	D	C	B	A	D	C	B	D	A	D	-	D	B	D	A
Nitric Acid (20% Solution)	-	A	A	A	D	A	A	D	-	D	-	B	A	B	A	A	D	D	D	B	A	C	D	C	D	A	D	-	D	D	D	B
Nitric Acid (50% Solution)	-	A	A	A	D	A	A	D	-	D	-	B	A	B	A	A	D	D	D	C	D	C	D	A	-	A	D	-	D	D	D	D
Nitric Acid (Concentrated Solution)	-	D	B	A	B	A	B	D	D	D	-	-	D	C	A	D	D	D	D	D	D	C	D	A	C	B	D	-	D	D	D	D
Nitrobenzene[2]	B	A	B	-	C	A	B	D	-	B	B	D	D	D	A	D	B	C	D	D	C	B	A	A	-	D	D	D	D	D	D	B
Oils																																
Aniline	-	A	A	-	C	A	D	A	-	A	-	-	D	-	A	D	D	C	D	-	A	-	A	A	-	A	D	-	D	B	D	A
Anise	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	-	-	-	D	-	-	A
Bay	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	-	-	D	-	-	A
Bone	-	A	A	-	-	-	-	A	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	D	-	-	A
Castor	-	A	A	-	A	-	-	A	-	A	-	-	A	-	-	-	A	-	-	-	-	-	A	A	A	A	A	-	A	B	A	A
Cinnamon	-	A	A	-	-	-	-	-	-	-	-	-	-	-	A	-	A	-	-	-	A	-	A	A	-	D	-	-	D	-	-	A

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Citric	-	A	A	-	-	-	-	D	-	D	-	-	-	-	-	-	A	A	-	-	A	-	A	A	-	A	A	-	D	-	-	A
Clove	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	A	-	-	B	-	A	A	-	-	A	-	-	-	-	A
Coconut	-	A	A	-	B	-	-	A	-	A	-	-	-	-	-	-	A	A	-	-	A	-	A	A	-	A	A	-	A	A	D	A
Cod Liver	-	A	A	-	B	-	-	-	-	-	-	-	-	-	-	-	A	A	C	-	A	-	A	A	-	A	A	-	B	A	D	A
Corn	-	A	A	A	B	-	-	B	-	A	-	-	-	-	-	-	A	A	C	-	A	-	A	A	-	A	A	-	D	C	D	A
Cotton Seed	B	A	A	A	B	-	-	B	-	A	C	-	A	-	A	-	A	A	C	-	A	A	A	A	-	A	A	-	D	C	D	A
Creosote[2]	-	A	A	-	A	-	-	-	-	-	-	-	-	-	-	-	D	-	-	-	D	-	A	A	-	A	A	-	B	D	D	A
Diesel Fuel (2D, 3D, 4D, 5D)	-	A	A	-	A	-	-	A	-	-	-	-	-	-	-	D	A	A	-	-	A	A	A	A	-	A	A	-	D	D	D	A
Fuel (1, 2, 3, 5A, 5B, 6)	-	A	A	-	A	A	A	A	-	-	-	-	A	-	A	D	A	-	-	-	B	-	A	A	-	A	B	-	D	D	D	A
Ginger	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	A	-	-	A
Hydraulic (See Hydraulic)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lemon	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	D	-	A	A	-	A	-	-	D	-	-	A
Linseed	-	A	A	A	A	-	-	A	-	A	-	-	A	B	-	-	A	A	C	-	A	-	A	A	A	A	A	-	D	D	D	A
Mineral	A	A	A	A	A	-	-	A	-	A	B	-	A	-	-	B	A	A	-	-	B	A	A	A	A	A	A	-	B	D	D	A
Olive	A	A	A	-	A	-	-	B	-	A	B	-	A	-	A	-	A	A	-	-	A	-	A	A	-	A	A	C	B	-	D	A
Orange	-	A	A	-	-	-	-	-	-	-	-	-	-	-	A	-	A	A	-	-	A	-	A	A	-	A	A	-	D	-	-	A
Palm	-	A	A	-	A	-	-	B	-	-	-	-	A	-	-	-	A	A	-	-	-	-	A	A	-	A	A	-	D	-	-	A
Peanut[3]	-	A	A	-	A	-	-	A	-	A	-	-	A	-	-	-	A	-	-	-	D	-	A	A	-	A	A	-	D	-	D	A
Peppermint[2]	-	A	A	-	-	-	-	A	-	-	-	-	-	-	-	-	A	-	-	-	D	-	A	A	-	A	D	-	D	-	-	A
Pine	A	A	A	-	A	-	-	D	-	C	B	-	A	-	A	-	A	-	-	-	-	-	A	A	-	A	A	-	D	-	D	A
Rape Seed	-	A	A	-	-	-	-	A	-	-	-	-	A	-	-	-	A	-	-	-	-	-	A	A	-	A	B	-	D	-	D	A
Rosin	-	A	A	-	A	-	-	-	-	-	-	-	-	-	-	-	A	A	-	-	A	-	A	A	-	A	A	-	-	-	-	A
Sesame Seed	-	A	A	-	A	-	-	A	-	A	-	-	A	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	D	-	-	A
Silicone	-	A	A	-	-	-	-	A	-	A	-	-	-	-	-	A	A	A	-	-	A	-	A	A	A	A	A	-	A	-	A	A
Soybean	-	A	A	-	A	-	-	B	-	A	-	-	A	-	-	-	A	A	-	-	A	-	A	A	-	A	A	-	D	-	D	A
Sperm	-	A	A	-	-	-	-	A	-	-	-	-	A	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	D	-	-	A
Tanning	-	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	D	-	-	A
Turbine	-	A	A	-	A	-	-	A	-	A	-	-	A	-	-	-	A	-	C	-	-	-	A	A	-	A	A	-	D	-	D	A
Oleic Acid	B	A	A	B	B	-	B	B	C	C	C	-	A	C	A	C	B	A	B	D	C	-	A	A	-	D	B	D	D	D	D	A
Oleum (25%)	-	-	-	-	-	-	A	-	-	-	-	B	D	-	A	D	-	-	-	-	-	-	-	A	-	A	D	D	D	D	-	D
Oleum	B	-	A	-	B	-	-	C	C	-	B	D	D	-	A	-	D	-	-	-	D	-	-	A	-	A	C	D	D	D	D	A
Oxalic Acid (Cold)	C	A	B	A	C	C	B	B	C	D	D	-	A	B	A	C	C	D	-	A	A	-	A	A	-	A	B	C	B	A	C	A
Paraffin	A	A	A	A	A	-	-	A	-	B	B	A	A	-	A	B	A	A	B	-	A	-	A	A	-	A	A	-	-	-	-	A
Pentane	A	C	C	-	A	-	B	A	-	B	B	-	-	-	A	D	A	A	D	-	-	-	A	A	-	A	A	-	B	D	D	A
Perchloroethylene[2]	B	A	A	-	A	-	-	C	-	B	B	A	-	-	A	D	A	-	D	-	D	A	A	A	-	A	C	D	D	D	D	A
Petrolatum	A	-	A	-	B	-	-	B	-	C	C	-	-	-	A	D	A	A	B	-	-	-	A	A	-	A	A	-	B	A	D	A
Phenol (10%)	B	A	A	-	A	-	B	C	-	B	D	-	A	C	A	-	-	D	-	-	-	A	-	-	-	B	D	-	C	D	C	C
Phenol (Carbolic Acid)	B	A	A	A	B	C	A	B	D	D	D	A	A	C	A	C	D	D	-	D	B	A	A	D	A	A	D	-	D	D	D	B
Phosphoric Acid (to 40% Solution)	-	B	A	A	D	A	A	D	D	D	-	-	A	B	A	A	D	D	C	B	A	A	B	C	D	A	D	-	D	B	C	A
Phosphoric Acid (40%-100% Solution)	-	C	B	B	D	B	A	D	D	D	-	-	A	B	A	A	D	D	D	C	A	A	B	D	D	A	D	-	D	B	C	C
Phosphoric Acid (Crude)	-	D	C	C	D	C	A	D	D	D	D	A	-	-	A	-	D	D	D	C	-	A	C	D	-	A	D	-	D	B	-	A
Phosphoric Anhydride (Dry or Moist)	-	A	A	-	-	-	-	-	D	-	-	-	D	D	A	-	-	-	-	-	-	-	-	A	-	D	D	-	D	-	A	-
Phosphoric Anhydride (Molten)	-	A	A	-	D	-	-	D	D	-	-	-	D	-	A	-	-	A	-	D	-	-	-	-	-	D	C	-	D	-	D	A
Photographic Developer	-	C	A	C	C	A	A	-	-	D	-	-	A	-	-	A	C	-	-	B	A	-	A	A	-	A	A	-	A	-	-	A
Phthalic Anhydride	B	A	B	-	B	-	A	B	-	C	C	-	-	-	A	-	-	A	-	-	-	-	-	-	-	A	C	-	-	-	-	-
Picric Acid	B	A	A	-	C	-	A	D	D	D	D	-	A	A	A	-	-	A	-	A	-	-	-	-	-	A	A	D	A	-	A	A
Plating Solutions																																
Antimony Plating 130°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	A	-	A	A	D	A	-	-	B
Arsenic Plating 110°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	C	-	A	A	D	A	-	-	B
Brass Plating																																
Regular Brass Bath 100°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	C	-	A	A	D	A	-	-	B
High Speed Brass Bath 110°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	D	-	A	A	D	A	-	-	B
Bronze Plating																																
Copper-Cadmium Bronze Bath R.T.	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	C	-	A	A	D	A	-	-	B
Copper-Tin Bronze Bath 160°F	-	-	A	-	-	A	A	-	-	-	-	-	D	-	A	A	-	A	-	-	A	-	-	D	-	A	A	D	B	-	-	C
Copper-Zinc Bronze Bath 100°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	C	-	A	A	-	A	-	-	B

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Cadmium Plating																																
Cyanide Bath 90°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	C	-	A	A	-	A	-	-	B
Fluoborate Bath 100°F	-	-	A	-	-	D	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	B
Chromium Plating																																
Chromic-Sulfuric Bath 130°F	-	-	C	-	-	A	A	-	-	-	-	-	A	-	A	D	-	D	-	-	A	-	-	A	-	C	D	-	D	-	-	D
Fluosilicate Bath 95°F	-	-	C	-	-	C	A	-	-	-	-	-	A	-	A	D	-	D	-	-	A	-	-	B	-	C	D	-	D	-	D	D
Fluoride Bath 130°F	-	-	D	-	-	C	A	-	-	-	-	-	A	-	A	D	-	D	-	-	A	-	-	B	-	C	D	-	D	-	-	D
Black Chrome Bath 115°F	-	-	C	-	-	A	A	-	-	-	-	-	A	-	A	D	-	D	-	-	A	-	-	A	-	C	D	-	D	-	-	D
Barrel Chrome Bath 95°F	-	-	D	-	-	C	A	-	-	-	-	-	A	-	A	D	-	D	-	-	A	-	-	A	-	C	D	-	D	-	-	D
Copper Plating (Cyanide)																																
Copper Strike Bath 120°F	-	-	-	-	A	A	A	-	-	-	-	-	-	-	A	A	-	-	-	-	-	-	-	C	-	B	-	-	A	-	-	-
Rochelle Salt Bath 150°F	-	-	A	-	-	A	A	-	-	-	-	-	D	-	A	A	-	A	-	-	A	-	-	D	-	A	A	-	B	-	-	C
High Speed Bath 180°F	-	-	A	-	-	A	A	-	-	-	-	-	D	-	A	A	-	A	-	-	A	-	-	D	-	A	A	-	B	-	-	C
Copper Plating (Acid)																																
Copper Sulfate Bath R.T.	-	-	D	-	-	A	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	A	-	A	-	-	D
Copper Fluoborate Bath 120°F	-	-	D	-	-	D	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	D
Copper (Misc.)																																
Copper Pyrophosphate 140°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	B	-	A	A	-	A	-	-	B
Copper (Electroless) 140°F	-	-	-	-	-	-	-	D	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	D	-	A	D	-	D	-	-	B
Gold Plating																																
Cyanide 150°F	-	-	A	-	-	A	A	C	-	-	-	-	D	-	A	A	-	A	-	-	A	-	-	B	-	A	A	-	A	-	-	D
Neutral 75°F	-	-	C	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Acid 75°F	-	-	C	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Indium Sulfamate Plating R.T.	-	-	C	-	-	A	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Iron Plating																																
Ferrous Chloride Bath 190°F	-	-	D	-	-	A	D	-	-	-	-	-	D	-	A	A	-	D	-	-	C	-	-	A	-	A	B	-	D	-	-	D
Ferrous Sulfate Bath 150°F	-	-	C	-	-	A	A	-	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	B	-	-	D
Ferrous Am. Sulfate Bath 150°F	-	-	C	-	-	A	A	-	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	B	-	-	D
Sulfate-Chloride Bath 160°F	-	-	D	-	-	A	D	-	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	A	-	A	B	-	C	-	-	D
Fluoborate Bath 145°F	-	-	D	-	-	D	B	-	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	D
Sulfamate 140°F	-	-	D	-	-	A	B	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Lead Fluoborate Plating	-	-	C	-	-	D	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	A
Nickel Plating																																
Watts Type 115-160°F	-	-	D	-	-	A	D	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	A	-	-	A
High Chloride 130-160°F	-	-	C	-	-	A	A	-	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	B	-	-	D
Fluoborate 100-170°F	-	-	C	-	-	D	A	D	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	D
Sulfamate 100-140°F	-	-	C	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Electroless 200°F	-	-	-	-	-	-	-	-	-	-	-	-	D	-	A	D	-	D	-	-	D	-	-	A	-	A	D	-	D	-	-	B
Rhodium Plating 120°F	-	-	D	-	-	D	D	-	-	-	-	-	A	-	A	A	D	D	-	-	A	-	-	A	-	A	A	-	B	-	-	A
Silver Plating 80-120°F	-	-	A	-	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	B	-	A	A	-	A	-	-	A
Tin-Fluoborate Plating 100°F	-	-	C	-	-	D	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	A
Tin-Lead Plating 100°F	-	-	C	-	-	D	A	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	A
Zinc Plating																																
Acid Chloride 140°F	-	-	D	-	-	A	D	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	A	-	-	A
Acid Sulfate Bath 150°F	-	-	C	-	-	A	A	-	-	-	-	-	D	-	A	A	-	D	-	-	A	-	-	A	-	A	A	-	B	-	-	D
Acid Fluoborate Bath R.T.	-	-	-	C	-	D	-	-	-	-	-	-	A	-	A	A	-	D	-	-	A	-	-	D	-	A	B	-	C	-	-	A
Alkaline Cyanide Bath R.T.	-	-	-	A	-	A	A	-	-	-	-	-	A	-	A	A	-	A	-	-	A	-	-	D	-	A	A	-	A	-	-	A
Potash	-	A	-	A	C	-	A	C	-	B	-	-	A	B	-	A	B	A	-	B	A	-	A	A	A	A	A	-	B	-	B	A
Potassium Bicarbonate	-	A	-	B	C	A	B	B	-	D	-	A	A	-	A	A	C	A	C	B	A	A	A	A	-	A	A	-	A	-	B	A
Potassium Bromide	A	A	-	B	C	A	B	C	-	D	D	A	A	-	A	A	A	C	-	B	A	C	A	A	-	A	A	-	A	A	B	A
Potassium Carbonate	B	A	-	A	C	A	A	C	-	B	B	A	A	B	A	A	B	A	-	B	A	A	A	A	A	A	B	-	A	-	B	A
Potassium Chlorate	B	A	A	A	B	A	B	B	-	B	B	A	A	B	A	A	B	D	-	B	A	A	A	A	-	A	A	-	A	-	B	A
Potassium Chloride	C	A	A	B	B	A	A	C	C	B	B	A	A	A	A	A	A	B	C	B	A	A	A	A	-	A	A	-	A	A	A	A
Potassium Chromate	-	-	B	B	A	-	B	A	-	A	-	-	A	-	-	A	C	-	-	B	-	A	A	D	-	A	A	-	A	-	B	C
Potassium Cyanide Solutions	B	A	B	A	D	A	A	D	-	B	B	A	A	-	A	A	C	A	-	B	A	A	C	A	-	B	A	-	A	A	A	A
Potassium Dichromate	B	A	A	A	A	A	B	C	-	B	C	A	A	-	A	A	C	D	-	B	A	A	A	A	-	B	A	-	A	A	A	A

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Potassium Ferrocyanide	B	A	-	A	C	-	B	A	-	-	C	-	A	-	A	-	-	A	-	A	-	-	-	-	-	-	D	-	-	-	A	A
Potassium Hydroxide (50%)	A	B	B	B	D	C	A	D	D	C	A	D	A	B	A	A	D	A	C	B	A	A	-	D	A	D	B	C	A	A	C	A
Potassium Nitrate	B	A	B	A	B	A	B	B	-	-	B	A	A	C	A	A	B	C	-	B	A	C	A	A	-	B	A	-	A	A	A	A
Potassium Permanganate	B	A	B	B	B	B	B	B	-	B	B	A	A	-	A	A	C	D	C	B	B	A	A	A	-	B	A	-	A	-	B	B
Potassium Sulfate	B	A	B	B	A	A	A	B	B	B	B	A	A	A	A	A	B	C	-	B	A	A	A	A	-	A	A	C	A	A	C	A
Potassium Sulfide	A	A	-	A	B	-	B	B	-	B	B	-	A	-	A	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-
Propane (Liquified)[1 2]	A	A	-	A	A	-	-	A	A	-	B	-	D	-	A	D	A	A	-	-	D	-	A	A	-	A	A	D	B	D	D	A
Propylene Glycol	B	B	-	A	A	-	-	B	-	B	B	-	-	-	A	-	B	B	B	B	-	-	A	A	-	A	A	-	C	-	-	A
Pyridine	-	C	-	B	B	-	-	-	-	B	A	D	-	D	A	D	D	-	-	C	B	A	A	A	-	D	D	-	D	B	D	A
Pyrogallic Acid	B	A	A	A	B	-	A	B	-	B	B	-	A	-	A	-	D	A	-	-	-	-	A	A	-	A	A	-	-	-	-	A
Rosins	A	A	A	A	A	-	B	A	C	-	C	-	-	-	A	-	B	A	-	-	A	-	A	A	-	-	A	-	-	-	-	A
Rum	-	A	-	A	-	-	-	-	-	-	-	-	A	-	-	A	A	A	-	-	A	-	A	A	-	A	A	-	A	-	-	A
Rust Inhibitors	-	A	-	A	-	-	-	A	-	A	-	-	-	-	-	-	A	-	-	-	A	-	A	A	-	A	A	-	C	-	-	A
Salad Dressing	-	A	-	A	B	-	-	B	-	D	-	-	A	-	-	A	A	A	-	-	A	-	A	A	-	A	A	-	-	-	-	A
Sea Water	A	A	C	A	C	A	-	C	-	-	D	-	A	-	A	A	A	A	-	B	A	-	A	A	A	A	A	B	B	A	A	A
Shellac (Bleached)	A	A	-	A	A	-	-	A	B	B	A	-	-	-	A	-	A	A	-	-	A	-	-	A	-	-	A	-	-	-	-	A
Shellac (Orange)	A	A	-	A	A	-	-	A	C	C	A	-	-	-	A	-	A	A	-	-	A	-	-	A	-	-	A	-	-	-	-	A
Silicone	-	B	-	A	B	-	-	A	-	-	-	-	-	-	-	A	A	A	-	-	A	-	A	A	-	A	A	B	A	A	A	A
Silver Bromide	-	C	C	B	D	-	-	-	-	-	-	-	-	-	-	A	C	-	-	-	-	-	A	-	-	-	-	-	-	-	-	A
Silver Nitrate	B	A	B	A	D	A	A	D	-	D	D	A	A	B	A	A	C	A	-	B	A	-	A	A	-	A	C	-	A	C	A	A
Soap Solutions[1]	A	A	A	A	C	A	B	B	-	B	A	-	B	B	A	A	A	A	-	B	A	A	A	A	A	A	A	B	B	-	C	A
Soda Ash (See Sodium Carbonate)	-	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sodium Acetate	B	A	A	B	B	A	-	B	-	C	C	A	A	-	A	A	B	A	-	B	A	-	A	A	-	D	D	-	C	-	A	A
Sodium Aluminate	B	-	-	A	C	B	B	B	-	-	C	-	-	-	A	A	B	A	-	-	-	A	A	A	-	A	A	-	A	A	B	A
Sodium Bicarbonate	B	A	A	A	A	A	-	B	A	C	C	A	A	B	A	A	B	A	B	B	A	A	A	A	A	A	A	C	A	A	A	A
Sodium Bisulfate	A	A	-	A	D	B	B	C	C	D	D	A	A	B	A	A	B	C	C	B	A	A	A	A	-	B	A	C	A	-	A	A
Sodium Bisulfite	-	A	-	A	A	A	B	C	-	D	-	A	A	B	A	A	B	D	B	B	A	A	A	A	-	A	A	C	A	-	A	A
Sodium Borate	B	A	-	A	C	-	A	A	-	C	C	-	C	-	A	-	-	A	-	A	-	-	-	-	-	A	-	B	A	-	-	-
Sodium Carbonate	B	A	B	B	C	A	A	B	B	B	B	A	A	B	A	A	A	A	C	B	A	A	B	A	-	A	A	-	A	A	A	A
Sodium Chlorate	B	A	-	A	B	A	B	B	-	-	C	A	A	B	A	A	D	A	-	B	A	A	A	A	-	A	D	-	A	-	A	A
Sodium Chloride	B	A	C	B	C	A	A	B	C	B	C	A	A	B	A	A	A	A	B	B	A	A	A	A	A	A	A	C	A	A	B	A
Sodium Chromate	A	A	A	-	D	-	B	B	-	B	B	-	-	-	A	A	D	A	-	-	A	A	A	B	-	B	A	-	A	-	-	C
Sodium Cyanide	B	A	-	A	D	A	-	D	D	B	B	A	A	-	A	A	D	C	-	B	A	A	A	A	-	A	A	D	A	A	A	A
Sodium Fluoride	B	C	-	C	C	A	A	C	-	D	D	-	D	D	A	-	-	A	-	C	-	-	-	-	-	B	D	-	D	-	D	A
Sodium Hydrosulfite	-	-	-	-	A	-	A	C	-	-	-	-	C	A	A	-	-	A	-	-	-	-	-	A	-	A	-	-	A	-	A	-
Sodium Hydroxide (20%)	-	A	A	A	D	A	A	C	D	A	-	A	A	B	A	A	D	C	C	B	A	A	C	D	A	A	A	D	B	A	A	A
Sodium Hydroxide (50% Solution)	-	A	B	-	D	A	A	C	D	B	-	D	A	B	A	A	D	C	C	C	A	B	C	D	A	D	D	D	C	-	A	A
Sodium Hydroxide (80% Solution)	-	A	D	-	D	A	B	C	D	C	-	-	A	B	A	A	D	C	C	C	A	B	C	D	A	B	D	D	C	-	B	A
Sodium Hypochlorite[3] (to 20%)	-	C	C	C	C	A	A	D	D	D	-	-	A	B	A	A	D	A	-	B	C	C	D	A	B	A	C	D	D	B	C	B
Sodium Hypochlorite	D	-	D	-	D	A	A	D	-	D	D	A	A	-	A	A	-	A	-	-	C	C	-	D	-	B	B	C	A	-	-	A
Sodium Hyposulfate	-	A	A	-	D	-	-	D	-	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	C	C
Sodium Metaphosphate[2]	A	-	A	-	A	-	-	C	C	B	B	-	-	-	A	-	B	A	-	-	D	-	A	A	-	A	A	-	B	A	A	A
Sodium Metasilicate	A	-	A	-	B	-	-	B	-	C	C	-	-	-	A	-	D	-	-	-	-	-	A	-	-	A	A	D	A	-	-	A
Sodium Nitrate	B	A	A	A	A	A	B	B	C	A	B	A	A	B	A	A	B	A	-	B	A	-	A	A	A	D	C	D	B	A	C	A
Sodium Perborate	B	-	C	-	B	-	-	C	C	B	B	-	-	-	A	A	B	A	-	-	A	-	A	A	-	A	B	D	B	A	C	A
Sodium Peroxide	B	A	A	-	C	-	B	C	C	D	C	-	A	-	A	-	D	D	-	-	-	-	A	A	-	A	C	D	B	A	C	A
Sodium Polyphosphate (Mono, Di, Tribasic)	-	A	A	-	D	A	A	C	-	-	-	-	-	-	A	A	B	-	-	-	-	-	A	A	-	A	A	-	D	A	A	A
Sodium Silicate	B	A	B	A	C	A	B	C	C	-	B	-	A	B	A	A	C	A	-	-	A	-	A	A	-	A	A	-	A	A	A	A
Sodium Sulfate	B	A	A	C	B	A	B	B	B	A	B	-	A	-	A	A	B	A	-	B	A	A	A	A	-	A	A	-	A	A	C	A
Sodium Sulfide	B	A	B	-	D	A	B	D	D	A	B	-	A	B	A	A	B	A	-	B	A	A	A	A	-	A	C	-	A	A	C	A
Sodium Sulfite	-	C	C	-	C	A	A	C	-	A	-	-	A	A	A	-	-	D	-	A	-	-	A	A	-	A	A	-	A	-	A	A
Sodium Tetraborate	-	-	A	-	-	-	-	-	-	-	-	-	A	-	-	A	B	-	-	-	-	-	A	A	-	A	A	-	-	-	-	A
Sodium Thiosulfate ("Hypo")	A	A	A	-	B	A	-	D	D	C	B	-	A	-	A	A	C	A	-	-	A	A	A	A	-	A	B	-	A	A	C	A
Sorghum	-	A	A	-	-	-	-	-	-	A	-	-	-	-	-	-	A	A	-	-	-	-	A	A	-	A	A	-	A	-	-	A
Soy Sauce	-	A	A	-	A	-	-	A	-	D	-	-	-	-	-	A	A	A	-	-	-	-	A	A	-	A	A	-	A	-	D	A
Stannic Chloride	D	D	D	-	D	A	B	D	-	D	D	A	A	-	A	A	C	A	-	B	A	-	-	A	-	A	A	D	A	A	A	A

	302 Stainless Steel	304 Stainless Steel	316 Stainless Steel	440 Stainless Steel	Aluminium	Titanium	Hastelloy C	Cast Bronze	Brass	Cast Iron	Carbon Steel	Kynar	PVC (Type 1)	Tygon (E-3606)	FEP/PTFE	Noryl	Polyacetal	Nylon	Cycolac (ABS)	Polyethylene	Polypropylene	Ryton	Carbon	Ceramic	Ceramagnet "A"	Viton	Buna-N (Nitrile)	Silicon	Neoprene	Ethylene Propylene	Rubber (Natural)	Epoxy
Stannic Fluoborate	-	-	A	-	-	-	-	-	-	D	-	-	-	-	-	A	C	-	-	-	-	-	-	A	-	A	A	-	A	-	-	A
Stannous Chloride	D	D	C	-	D	A	A	D	-	D	D	-	A	A	A	-	-	D	-	A	-	-	-	-	-	B	C	D	D	-	A	A
Starch	B	A	A	-	A	-	-	B	-	C	C	-	A	-	A	A	A	A	-	B	-	-	A	A	-	A	A	-	A	-	-	A
Stearic Acid[2]	B	A	A	A	B	A	A	C	C	C	C	A	A	B	A	A	A	A	-	B	D	-	A	A	A	A	B	D	B	B	C	A
Stoddard Solvent	A	A	A	A	A	A	A	A	A	B	B	A	A	D	A	D	A	A	B	D	D	A	A	A	-	A	B	D	D	D	D	A
Styrene	A	A	A	-	A	-	-	A	-	-	A	-	-	-	A	A	A	-	-	-	-	-	A	A	-	B	D	D	D	D	D	A
Sugar (Liquids)	A	A	A	A	A	-	A	A	-	B	B	-	-	-	A	A	A	A	B	-	A	-	A	A	A	A	A	-	B	-	A	A
Sulfate Liquors	-	C	C	-	B	-	A	C	-	-	-	-	-	-	-	-	D	-	-	-	A	-	A	A	-	-	-	-	C	-	-	A
Sulfur Chloride	-	D	D	D	D	-	-	C	D	-	-	-	A	C	A	A	D	A	-	A	D	-	A	C	-	A	D	-	D	D	D	C
Sulfur Dioxide[2]	-	A	A	C	A	A	B	B	-	-	-	B	D	B	A	D	B	D	D	C	D	A	A	A	-	D	D	C	B	A	D	A
Sulfur Dioxide (Dry)	A	A	A	-	A	-	A	A	C	A	B	-	D	-	A	-	-	A	-	D	-	-	A	A	-	D	-	-	D	-	D	D
Sulfur Trioxide (Dry)	A	A	C	-	A	-	-	B	-	B	B	-	A	B	A	D	D	D	-	-	-	-	B	A	-	A	D	-	D	B	C	A
Sulfuric Acid (to 10%)	-	D	C	C	C	A	A	D	D	D	-	A	A	B	A	A	D	D	B	B	A	A	A	A	-	A	C	-	D	D	C	A
Sulfuric Acid (10%-75%)[2]	-	D	D	D	D	C	B	D	D	D	-	A	A	B	A	B	D	D	B	C	A	B	A	D	C	A	D	-	D	D	D	B
Sulfuric Acid (75%-100%)	-	-	D	-	-	D	B	-	D	-	-	A	B	-	A	A	-	D	-	-	B	C	-	A	-	A	D	-	D	-	-	D
Sulfurous Acid	C	C	B	C	C	A	B	D	-	D	D	-	A	B	A	A	D	D	-	B	A	-	B	A	-	A	C	D	B	B	C	A
Sulfuryl Chloride	-	-	-	-	-	-	-	-	-	-	-	-	A	-	A	-	-	-	-	-	-	-	-	A	-	-	-	-	-	-	-	A
Syrup	-	A	A	A	A	-	-	D	-	-	-	-	A	-	-	A	A	A	B	-	A	-	A	A	A	A	A	-	B	-	A	A
Tallow	-	A	A	-	A	-	-	-	-	-	-	-	-	-	-	A	A	A	-	C	-	-	A	A	-	A	A	-	-	-	-	A
Tannic Acid	B	A	A	A	C	A	B	B	-	C	C	A	A	B	A	A	B	D	-	B	A	-	A	A	A	A	D	C	A	A	A	A
Tanning Liquors	-	A	A	-	C	A	A	A	-	-	-	-	A	B	A	-	B	-	-	-	A	-	A	A	-	A	C	-	-	-	-	A
Tartaric Acid	B	A	B	B	C	A	B	A	C	D	D	A	A	B	A	A	B	A	-	B	A	-	A	A	-	A	D	C	A	-	A	A
Tetrachlorethane	-	-	A	-	-	A	A	-	-	-	-	-	D	-	A	D	A	A	-	-	A	-	A	A	-	A	D	-	-	D	D	A
Tetrahydrofuran	-	A	A	-	D	-	-	D	-	D	A	D	D	-	A	D	A	A	-	D	C	A	A	A	-	D	D	-	D	B	D	A
Toluene, Toluol[3]	A	A	A	-	A	A	A	A	A	A	A	A	D	D	A	D	A	A	D	D	D	A	A	A	A	C	D	D	D	D	D	A
Tomato Juice	A	A	A	-	A	-	-	C	-	C	C	-	-	-	A	A	B	A	B	-	A	A	A	A	-	A	A	-	A	-	-	A
Trichlorethane	-	C	A	-	C	A	A	C	-	C	-	-	-	-	A	D	A	-	-	-	-	-	A	A	-	A	D	D	D	D	D	A
Trichlorethylene[2]	B	A	A	-	B	A	A	B	A	C	B	A	D	-	A	D	A	C	D	D	D	C	A	A	C	A	D	D	D	D	D	A
Trichloropropane	-	-	A	-	-	-	-	A	-	-	-	-	-	-	-	D	A	-	D	-	-	-	A	A	-	A	A	-	A	-	-	A
Tricresylphosphate	-	-	A	-	-	B	A	A	-	-	-	-	D	-	A	A	C	-	-	-	-	-	A	A	-	B	D	-	D	A	-	A
Triethylamine	-	-	-	-	-	-	-	A	-	-	-	-	A	-	-	B	D	-	-	-	-	-	A	A	-	A	A	D	B	-	-	A
Turpentine[3]	B	A	A	-	C	-	A	B	C	B	B	A	A	B	A	D	A	A	-	D	B	A	A	A	-	A	D	-	D	D	D	A
Urine	-	A	A	-	B	-	-	C	-	B	-	-	A	-	-	A	A	A	-	B	A	-	A	A	-	A	A	-	D	A	-	A
Vegetable Juice	-	A	A	-	A	-	-	C	-	D	-	-	-	-	-	A	A	A	-	-	-	-	A	A	-	A	A	B	D	-	D	A
Vinegar	A	A	A	A	D	A	A	B	B	C	D	A	A	-	A	A	B	A	B	B	A	A	A	A	A	A	C	-	B	A	C	A
Varnish (Use Viton for Aromatic)	A	A	A	A	A	-	-	A	B	-	C	-	-	-	A	D	A	A	-	-	A	-	A	A	A	A	B	C	D	-	D	A
Water, Acid, Mine	-	A	A	-	C	-	-	C	D	C	-	-	A	B	-	A	D	A	B	-	A	B	A	A	-	A	A	-	B	-	B	A
Water, Distilled, Lab Grade 7	-	A	A	-	B	-	-	A	-	D	-	-	A	B	A	A	A	A	A	-	A	A	A	A	A	A	A	-	B	A	A	A
Water, Fresh	A	A	A	-	A	-	-	A	C	B	D	-	A	B	A	A	A	A	A	A	A	A	A	A	A	A	A	-	B	A	A	A
Water, Salt	-	A	A	-	B	-	-	B	C	D	-	-	A	B	-	A	A	A	-	-	A	A	A	A	A	A	A	-	B	A	A	A
Weed Killers	-	A	A	-	C	-	-	C	-	-	-	-	-	-	-	-	A	A	-	-	-	-	A	A	-	A	B	-	C	-	-	A
Whey	-	A	A	-	B	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	A	A	-	-	-	-	A
Whiskey and Wines	A	A	A	A	D	-	-	B	B	D	D	-	A	-	A	A	A	A	-	B	A	-	A	A	-	A	A	B	A	A	A	A
White Liquor (Pulp Mill)	-	A	A	-	-	-	A	D	-	C	-	-	A	-	A	A	D	A	-	-	A	-	A	A	-	A	A	-	A	-	-	A
White Water (Paper Mill)	-	A	A	-	-	-	-	A	-	-	-	-	-	-	-	-	B	A	-	-	A	-	A	A	-	A	-	-	A	-	-	A
Xylene[2]	A	A	A	-	A	-	A	A	A	A	B	A	D	-	A	D	A	A	D	D	D	A	A	A	A	A	D	D	D	D	D	A
Zinc Chloride	D	D	B	B	D	A	B	D	D	D	D	A	A	-	A	A	C	A	-	B	A	A	A	A	-	A	A	-	A	A	A	A
Zinc Hydrosulfite	-	-	A	-	D	-	-	D	-	D	-	-	-	-	-	A	C	-	-	-	-	A	A	A	-	-	A	-	A	A	-	A
Zinc Sulfate	B	A	A	A	D	A	B	B	C	C	D	A	C	B	A	A	C	A	-	B	A	A	A	A	-	A	A	-	A	A	C	A

Appendix 7: Stainless Steel Cross-Reference Chart

Stainless Steel Cross Reference Chart

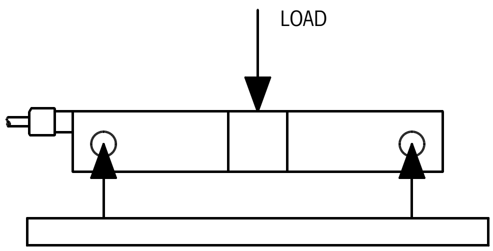
Term	China	Eu	France	Germany		Italy
		EURONORM	AFNOR	DIN	W. No	UNI
302	1Cr18Ni9	X 10 CrNi 18 9	Z 10 CN 18-09	X 5 CrNi 17 7	1.4319	X 10 CrNi 1809
304	0Cr18Ni9	X 6 CrNi 18 10	Z 6 CN 18-09	X 5 CrNi 18 10 X 5 CrNi 18 12	1.4301 1.4303	X 5 CrNi 1810
304L	00Cr18Ni10	X 3 CrNi 18 10	Z 2 CN 18-10	X 2 CrNi 18 11	1.4306	X 2 CrNi 1911
316	0Cr17Ni12Mo2	X 6 CrNiMo 17 13 3	Z 6 CND 17-12	X 5 CrNiMo 17 13 3	1.4436	X 5 CrNiMo 1713
316L	00Cr17Ni14Mo2	X 3 CrNiMo 17 12 2	Z 2 CND 17-12	X 2 CrNiMo 17 13 2	1.4404	X 2 CrNiMo 1712
420	2Cr13	X 20 Cr 13	Z 20 C 13	X 20 Cr 13	1.4021	
440A	7Cr17					
440B	8Cr17	X 90 Cr MoV 18	Z 2 CND 18 05	X 90 CrMoV 18	1.4112	
440C	9Cr18/11Cr17	X 90 Cr Mo 17	Z 100 CD 17	X 105 CrMo 17	1.4125	X 102 CrMo 17KU
17-4PH	0Cr17Ni4Cu4Nb		Z 6 CNU 17-04	X 5 CrNiCuNb 16.4	1.4542	

Term	Japan	Russia	Spain	Sweden	UK	USA
	JIS	GOST / GOST-R	UNE	SIS	BS	AISI
302	SUS302	12X18H9	X 10 CrNi 18-09	23 31	302S25	302
304	SUS304	08X18H10 06X18H11	X 6 CrNi 19-10	23 32 2333	304S15 304X16	304
304L	SUS304L	03X18H11	X 2 CrNi 19-10	23 52	304S11	304L
316	SUS316	08X17H13M2	X 6 CrNiMo 17-12-03	23 43 2348	316S33	316
316L	SUS316L	03X17H13M2	X 2 CrNiMo 17-12-03	23 48	316S11	316L
420	SUS420J2	20X13		2303	420 S 37	420
440A	SUS440A					440A
440B	SUS440B	95X18				440B
440C	SUS440C					440C
17-4PH	SUS630					630

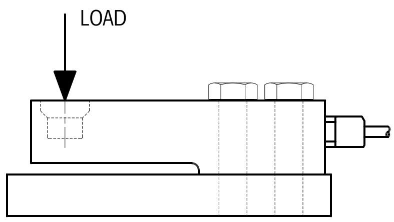
Equivalency may be approximate

11. Glossary

Accuracy – A scale's ability to provide a weight reading equal to the actual weight placed on the scale. A scale's accuracy is usually measured against a recognized standard, such as NIST Certified Test Weights.



Beam Load Cell, Double Ended – Double ended shear beam load cells are used in multiples under truck and floor scales and in tank, hopper and silo weighing. The longitudinal axis of the load cell is positioned horizontally with both ends supported; illustrated is one style where the ends have cross-drilled holes that rest on horizontal pins typically supported from a base plate. The load is introduced at the center of the load cell (the primary loading axis) typically by a clamp that provides liftoff protection also. There are many variations on this design, for example, in truck scales it is common to use a design where the load cell is supported at a single point in the center, while the load is introduced at both ends through swing-links hanging over "ears" on each end.

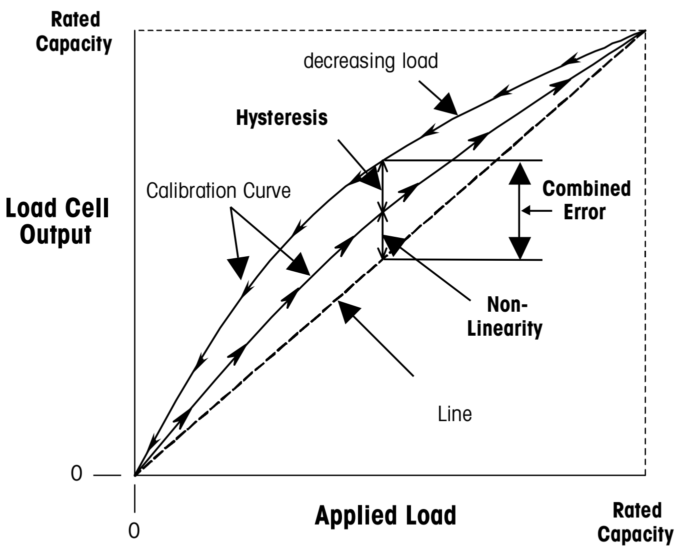


Beam Load Cell, Single Ended – Referred to variously as beam, cantilever beam, bending beam and shear beam load cells, these are used in multiples under floor and conveyor scales and in tank, hopper and silo weighing. The longitudinal axis of the load cell is positioned horizontally with the dead end of the load cell bolted to a horizontal base plate; the load is introduced along the center line of a vertical hole (the primary loading axis) at the free end of the cell. Ball/cup and rocker pin arrangements are commonly used as the interface between the load receiver and load cell; this allows the load receiver to expand/contract without imposing unwanted side forces on the cell, and produces a restoring force to keep the scale centered. Some load cells have a threaded hole for load introduction; this provides a tight coupling of the load receiver to load cell, which must be protected from extraneous forces to avoid poor performance. The load cell can also be rotated 180° from the position shown here, for example, when bolted upwards to the underside of a floor scale.

Calibration – The process of equating the graduations on a scale to the actual weight values that they represent. It involves adjusting the scale's indicator so that it reads zero when no weight is on the scale and reads the full weight capacity when that weight is placed on the scale.

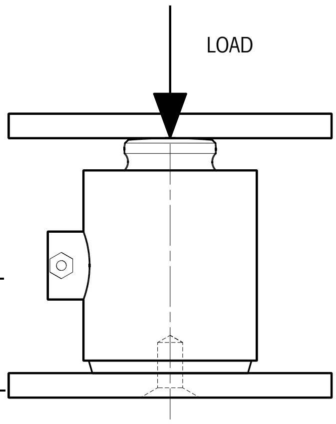
Calibration Curve – The characteristic curve obtained when load cell or scale output is plotted against applied load, as applied load is increased from zero to Rated Capacity and back to zero.

Canister Load Cell, Compression – This was



Calibration Curve

one of the first commercially available load cells and it remains in production despite the availability of competing designs today. Illustrated is a compression canister cell typical of those used in multiples under large platform scales such as truck and railroad track scales, and in tank, hopper and silo weighing. The longitudinal axis of the canister (the primary loading axis) is mounted vertically with the flat base sitting on a base plate and usually secured to it by screws from the underside. The upper surface has a button with a spherical radius and load is generally introduced using a hardened flat plate. Expansion and contraction is accommodated by the slippage of this plate on the load cell's button; the scale structure is generally held in position using horizontal check rods. Also available (though less common) is the tension canister used in tension applications.



Clevis – A U-shaped connector with holes drilled through the arms. A pin is fitted through the holes to attach the clevis to another component.

Combined Error – Error due to the combined effects of non-linearity and hysteresis. It is the maximum deviation (±) from a straight line drawn between a load cell's or scale's output at zero load and at Rated Capacity, measured with both increasing and decreasing loads, stated as a percentage of Rated Capacity. See Calibration Curve.

Compression – The act of squeezing or pressing down on a material. A compression weigh module is designed so that its top plate and base plate will be squeezed toward each other when weight is applied to it.

Creep – The change (±) in load cell or scale output occurring in a specified period of time while under constant load and with all environmental conditions and other variables remaining constant, stated as a percentage of applied load in 30 or 60 minutes.

Deflection – The bending or twisting of a material when force is applied to it.

Distributed Loading – A type of loading in which an object is placed on a scale so that its full weight is spread over all of the scale's load cells.

Dynamic Loading – A situation in which the weight applied to a scale is in motion. One example is a conveyor system used to weigh objects as they move along the conveyor.

Electromagnetic Interference (EMI) – The disturbance of an electrical device's operation that is caused when the device picks up electromagnetic radiation from an outside source.

Full End Loading – A type of loading in which an object is placed on a scale so that its full weight is temporarily concentrated over the load cells at one end of the scale. Full end loading is common with conveyor systems, where the object to be weighed moves across the scale from the front end to the back end.

Hermetic Seal – A metal cover welded or soldered in place to protect the strain gauges in a load cell. This type of watertight seal is commonly used for harsh environments.

Hysteresis – The maximum difference between load cell or scale output readings for the same applied load; one reading obtained by increasing the load from zero and the other by decreasing the load from Rated Capacity, stated as a percentage of Rated Capacity. In other words, it is the maximum difference between the Calibration Curve's increasing and decreasing load curves at a single load. See Calibration Curve.

Increment – The smallest change in weight that a digital scale can detect (also called a division).

Indicator – In a digital scale, the indicator is the part of the scale that receives analog signals transmitted by the load cells and displays them as weight readings.

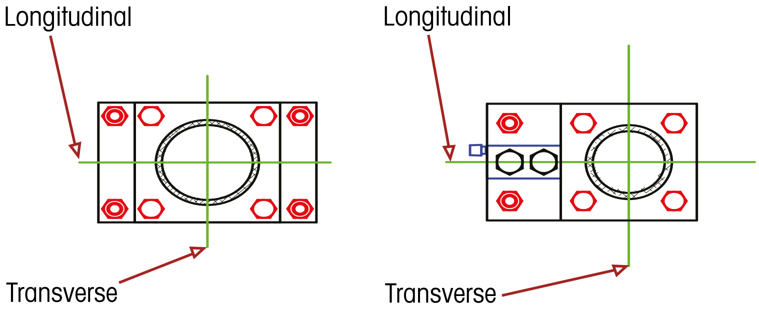
Live Load – The downward force exerted by an object or material being weighed on a scale.

Live-to-Dead Connection – A mechanical connection between a scale and an object that you do not want to weigh. A common example is piping connected to a tank scale. If the connection is not flexible enough to allow the scale to move freely, the piping can push or pull on the scale and produce inaccurate weight readings.

Load – A mechanical force applied to a scale or other object.

Load Cell – The component of a scale that detects the mechanical force exerted by a weight and converts it to an electrical signal.

Longitudinal Axis - In a horizontal plane, the Longitudinal Axis of a weigh module is the center line through the base plate that is parallel to the larger dimension of the plate.



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Max. Rated Forces - If Max. Rated Forces are not exceeded in normal day-to-day operation, then the weigh module can be expected to provide long service life without degradation of performance. These "rated" forces are analogous to the Rated Capacity specified for every load cell and weigh module, and should be used in normal circumstances in the absence of other information or design requirements. METTLER TOLEDO has applied a factor of safety to these specifications. Force ratings are provided in kN (or lb or klb).

Max. Yield Forces - If Max. Yield Forces are exceeded statically one time, then the weigh module may yield (i.e., may be distorted permanently) and may need to be replaced. Note that the Max Yield Force values do not consider the effects of fatigue or cyclic loading and should be approached only in exceptional circumstances. These values are provided for structural engineers who wish to apply their own factor of safety considering the application and desired outcome after a severe loading event such as a severe storm. Inspection of the installation after such an event is highly recommended. Force ratings are provided in kN (or lb or klb).

Max. Ultimate Forces - If Max. Ultimate Forces are exceeded one time statically, then the weigh module may fracture and proceed directly to the break point (i.e., physically pull apart or collapse) with potential for serious injury and/or property damage. Note that the weigh module will have yielded and may not weigh at all before the Max. Ultimate Force point has been reached. These values are provided for structural engineers who wish to apply their own factor of safety considering the application and desired outcome after a very severe loading event. An example is a major earthquake where the design parameters had specified that the installation must remain safe during the event, but that it was acceptable if the equipment was damaged beyond repair. Force ratings are provided in kN (or lb or klb).

Max. Compressive Force, Rated - This is the maximum vertically downward force for which the weigh module is rated in normal operation. It is stated in units of force and is simply a restatement of Rated Capacity, which is provided in units of mass. Force ratings are provided in kN (or lb or klb).

Max. Compressive Force, Yield - This is the maximum vertically downward static force that can be applied to the weigh module before the yield point may be reached. If exceeded once, the weigh module may yield and need replacement. Force ratings are provided in kN (or lb or klb).

Max. Compressive Force, Ultimate - This is the maximum vertically downward static force that can be applied to the weigh module before fracture may occur. If exceeded once, the weigh module may break with potential for serious injury and/or property damage. Note that MultiMount™ and PowerMount™ top plates will travel downward 5 mm (0.2 in) before the down-stop engages and this force rating can be developed. Force ratings are provided in kN (or lb or klb).

Max. Horizontal Force, Rated - This is the maximum horizontal force applied to the weigh module top plate for which the weigh module is rated in normal operation. It is specified independently for the transverse and longitudinal directions. Note that the top plate will travel laterally by 2.5 – 8 mm (0.1 – 0.2 in) before engaging the horizontal stop and the horizontal force can be resisted by the weigh module. See the Max. Top Plate Travel specification for the particular weigh module. Force ratings are provided in kN (or lb or klb).

Max. Horizontal Force, Yield - This is the maximum horizontal static force that can be applied to the weigh module top plate before the yield point may be reached. If exceeded once, the weigh module may yield and need replacement. It is specified independently for the transverse and longitudinal directions. Note that the top plate will travel laterally by 2.5 – 8 mm (0.1 – 0.2 in) before engaging the horizontal stop and the horizontal force can be resisted by the weigh module. See the Max. Top Plate Travel specification for the particular weigh module. Force ratings are provided in kN (or lb or klb).

Max. Horizontal Force, Ultimate - This is the maximum horizontal static force that can be applied to the weigh module top plate before fracture may occur. If exceeded once, the weigh module may break with potential for serious injury and/or property damage. It is specified independently for the transverse and longitudinal directions. Note that the top plate will travel laterally by 2.5 – 8 mm (0.1 – 0.2 in) before engaging the horizontal stop and the horizontal force can be resisted by the weigh module. See the Max. Top Plate Travel specification for the particular weigh module. Force ratings are provided in kN (or lb or klb).

Max. Uplift Force, Rated - This is the maximum vertically upward force (applied to the top plate) for which the weigh module is rated in normal operation. Note that on most weigh modules, the top plate will travel upward by 2 – 3 mm (0.08 – 0.12 in) before the anti-uplift stop is engaged and the weigh module can resist the uplift force. Force ratings are provided in kN (or lb or klb).

Max. Uplift Force, Yield - This is the maximum vertically upward static force that can be applied to the weigh module top plate before the yield point may be reached. If exceeded once, the weigh module may yield and need replacement. Note that on most weigh modules, the top plate will travel upward by 2 – 3 mm (0.08 – 0.12 in) before the anti-uplift stop is engaged and the weigh module can resist the uplift force. Force ratings are provided in kN (or lb or klb).

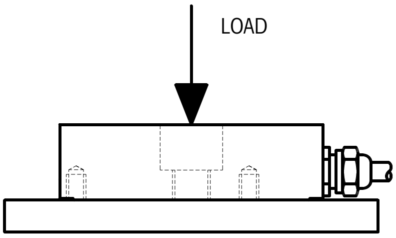
Max. Uplift Force, Ultimate - This is the maximum vertically upward static force that can be applied to the top plate before fracture may occur. If exceeded once, the weigh module may break with potential for serious injury and/or property damage. Note that on most weigh modules, the top plate will travel upward by 2 – 3 mm (0.08 – 0.12 in) before the anti-uplift stop is engaged and the weigh module can resist the uplift force. Force ratings are provided in kN (or lb or klb).

Max. Top Plate Travel - The maximum movement of a Compression Weigh Module's top plate in a horizontal plane relative to its base plate before engagement of the horizontal stops, specified in mm (or inches).

Max. Horizontal Travel - The maximum allowed movement of a Rocker Pin Load Cell's top button in a horizontal plane relative to its lower button, specified in mm (or inches).

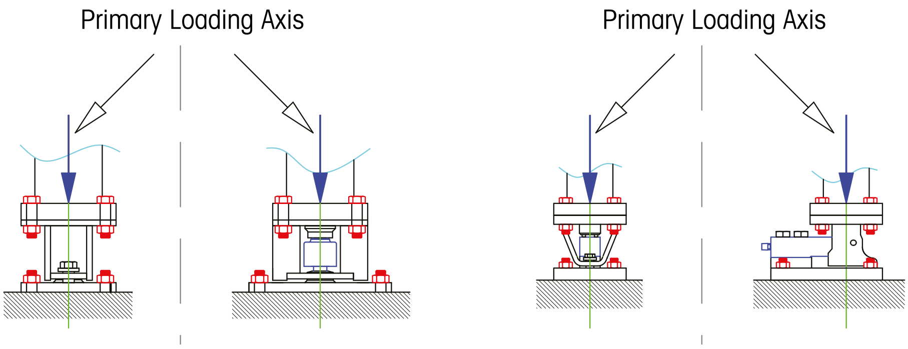
Non-Linearity – The maximum deviation (±) of a load cell or scale's calibration curve from a straight line drawn between the load cell's output at zero load and at Rated Capacity measured on increasing load, stated as a percentage of Rated Capacity. See Calibration Curve.

Pancake Load Cell – Pancake is a generic term used to describe low profile cylindrical load cells; other terms used are torsion ring, compression disk, shear web, wheel spoke and hockey puck. These load cells are used in multiples under truck, floor and conveyor scales and in tank, hopper and silo weighing. The load cell typically sits firmly on a flat plate while the load is introduced along the cylinder's axis (the primary loading axis). Typically a ball/cup or rocker pin arrangement is used as the interface between the load receiver and load cell; this allows the load receiver to expand/contract without imposing unwanted side forces on the cell, and produces a restoring force to keep the scale centered. Other designs have a raised button with spherical radius or a threaded hole for load introduction; these designs must be protected from extraneous forces to avoid poor performance or damage to the load cell. The load cell can also be rotated 180° from the position shown here, for example, when bolted upwards to the underside of a floor scale.



Potted Seal – A layer of organic sealing compound used to protect the strain gauges in a load cell. It is not as effective as a hermetic seal, which is often preferred for harsh environments.

Primary Loading Axis – The vertical axis along which a load cell, weigh module or scale is designed to be loaded. Also referred to as Axis Of Action.



* new image added: Table_A3.ai

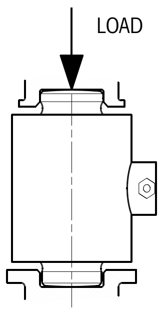
Radio Frequency Interference – The disturbance of an electrical device's operation that is caused when the device picks up radio frequency emissions from an outside source.

Rated Capacity (R.C.) – The maximum load that can be applied to a scale, weigh module or load cell on the primary loading axis if its performance is to remain within specification. Also referred to as Maximum Capacity with the abbreviations Max and Emax used for scales and load cells respectively. The Rated Capacity should not be exceeded. In the selection of load cells it is common practice to not exceed 50% to 80% of the Rated Capacity in use.

Rated Output – The output signal from the load cell when Rated Capacity is applied along its primary loading axis, stated in mV/V (mV of signal per V of excitation voltage applied to the load cell).

Repeatability Error – The maximum difference between load cell or scale output readings taken from consecutive tests under the same loading and environmental conditions of measurement, stated as a percentage of applied load.

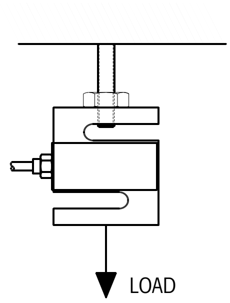
Rocker Pin Load Cell – A rocker pin (or rocker column) load cell is a compression cell used in multiples under large platform scales such as truck and railroad track scales, and in tank, hopper and silo weighing. The longitudinal axis of the pin (the primary loading axis) is



mounted vertically and its ends have spherical radii which contact hardened receivers; these hold the load cell and introduce the load at the central point of contact. This arrangement
allows the load cells to rock (tilt) to allow the load receiver expand/contract and to absorb horizontal shocks. The radii on the pin are selected so that the load receiver is lifted progressively with increasing tilt of the load cell, thus producing a restoring force which acts to "restore" the load cells to their optimum upright position and the load receiver to its centered position.

Resolution – A scale's ability to detect changes in weight. For a digital scale, resolution is measured in increment size, which is the smallest weight change that the scale can detect.

S-Type Load cell – S-Type (or S-Beam) load cells are typically used in tension individually or in multiples to weigh various load receivers such as suspended tanks and hoppers. Load is introduced to the load cell along the centerline passing through the threaded holes (the primary loading axis) in the upper and lower surfaces; threaded rods or various forms of hardware can be screwed into these holes for this purpose. With suspension rods of sufficient length, any amount of expansion/contraction can be accommodated without affecting performance. Suspended scales are considered when an overhead support structure already exists or where the floor area under the scale must be kept clear. S-type load cells are also used to convert mechanical scales to electronic particularly when digital output is required for control purposes; in this case an S-type load cell is inserted in the steelyard rod between the lever system and the original beam.



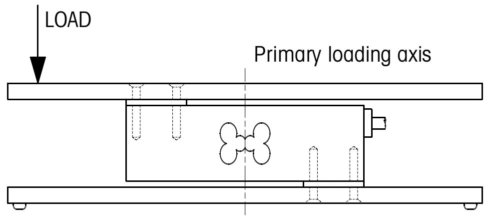
Safe Overload – The maximum weight that can be applied to a load cell without causing it to fail (typically 150% of rated capacity, consult the datasheet).

Seismic Loading – Forces exerted on a scale or its support structure by earthquakes or other vibrations of the earth.

Shear Force – A horizontal force exerted on a scale.

Shock Loading – Forces exerted on a scale or its support structure when an object strikes it. Shock forces can be created when an object is dropped on a scale or when a vehicle runs into a scale.

Single Point Load Cell – Single point (or moment insensitive) load cells are used individually to make bench scales and to weigh small conveyors, tanks and hoppers. They are mounted with their longitudinal axis horizontal typically between 2 plates or frames, the upper one being the load receiver. Ideally the load cell's vertical center line (the primary loading axis) is placed at the center of the load receiver; the unique feature of this cell is that it weighs within specification regardless of where the load is applied to the receiver. The upper and lower frames are usually mounted to the load cell's horizontal surfaces as shown, typically with spacer plates to create clearance to accommodate load cell deflection under load. Some models require mounting to the end faces (model IL, for example).



Spring Rate – A measure of a material's flexibility. The spring rate constant for a load cell is its rated capacity divided by load cell deflection at rated capacity.

Static Loading – A situation in which the load applied to a scale will be weighed while not in motion.

Strain Gauge – A wire or series of wires that measures the strain a force exerts on an object. When a strain gauge is attached to a load cell, it measures how much a weight causes the load cell to deflect. The strain gauge stretches as the load cell deflects, increasing the wire's resistance to an electric current being transmitted through it.

Temperature Effect on Minimum Dead Load output – Change (±) in load cell or scale minimum dead load output due to a change in ambient temperature, stated as a percentage of Rated Capacity per °C [or °F] change in ambient temperature. Also referred to as temperature effect on zero and temperature coefficient of zero.

Temperature Effect on Sensitivity – Change (±) in load cell or scale sensitivity due to a change in ambient temperature, stated as a percentage of applied load per °C [or °F] change in ambient temperature. Also referred to as temperature effect on span and temperature coefficient of span.

Temperature Range, Compensated - The temperature range over which a Load Cell or Scale is compensated to comply with its published metrological specifications, usually expressed in °C (or °F).

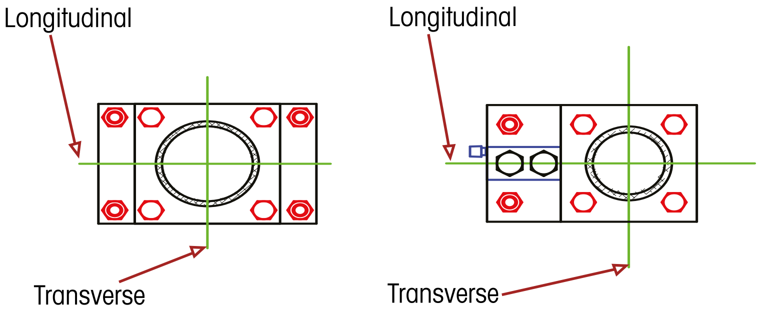
Temperature Range, Operating - The temperature range over which a Load Cell or Scale will operate without permanent adverse change to any of its performance characteristics, but may not comply with published specifications when the temperature is outside of the Compensated Temperature Range, usually expressed in °C (or °F).

Temperature Range, Safe Storage - The temperature range within which a Load Cell or Scale may be stored without electrical connection or mechanical loading, without causing deterioration of published specifications, usually expressed in °C (or °F).

Tension – The act of stretching a material. A tension weigh module is designed to stretch as weight is applied to it.

Transducer – A device used to convert energy from one form to another. A load cell is a transducer that converts a mechanical force (weight) to an electrical force (current) which can be used to provide a digital weight reading.

Transverse Axis - In a horizontal plane, the Transverse Axis of a weigh module is the axis at right angles to the Longitudinal Axis that passes through the center point of the top plate.



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Type Evaluation – The procedure used to test a particular type (or model) of weighing device. In the United States, the National Type Evaluation Program (NTEP) tests a sample of each model of scale. If the tests show that a scale complies with the requirements of NIST Handbook 44, NTEP issues a Certificate of Conformance for that model of scale.

Ultimate Overload – The weight at which a load cell will structurally fail (typically 300% of rated capacity, consult the datasheet).

Weigh Module – A device that can be attached to a tank or other structure to convert the structure into a scale. Weigh modules are attached to a structure so that they support its full weight. A weigh module system should be designed to provide accurate weight readings and support the structure safely.

Weighbridge – A scale platform. It is designed to transfer the load placed on it to the scale's load cells.

Wind Loading – Forces exerted on a scale or its support structure by wind currents.

Zero Load Output – The maximum output (±) from the load cell when no load is applied along its primary loading axis, stated as a percentage of Rated Capacity

12. Index

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