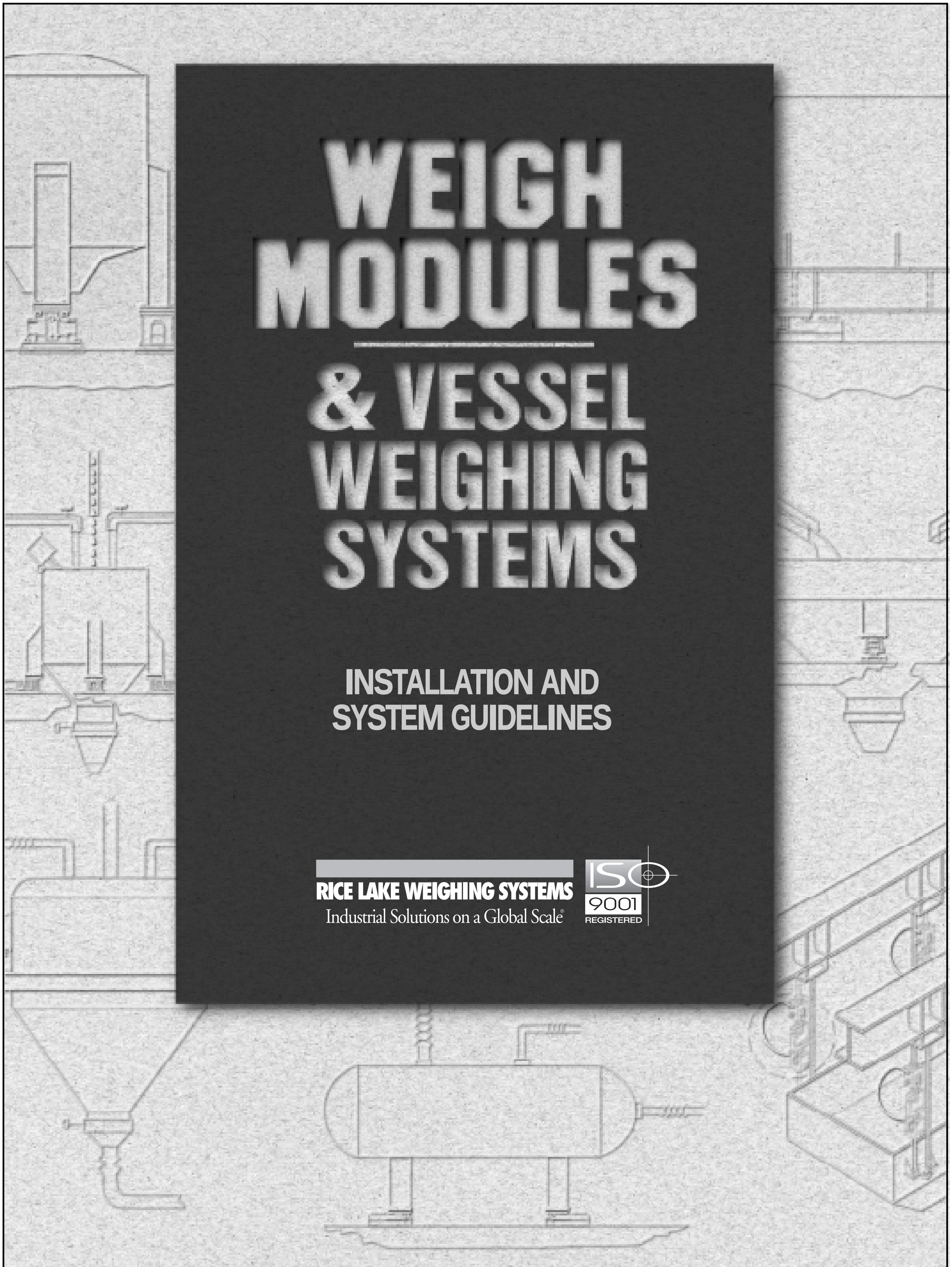


WEIGH MODULES

& VESSEL WEIGHING SYSTEMS

INSTALLATION AND SYSTEM GUIDELINES

RICE LAKE WEIGHING SYSTEMS
Industrial Solutions on a Global Scale®

ISO 9001 REGISTERED

CONTENTS

Warning All vessel weighing system installations should be planned by a qualified structural engineer. This manual is intended to serve only as a general guide to planning, installation, and servicing of these systems; no attempt has been made to provide a comprehensive study of all possible system configurations.

December 1997

VESSEL WEIGHING SYSTEM DESIGN

Bulk Material Weighing Systems

Bulk materials are weighed for various reasons. Although this discussion focuses on the weighing of bulk solids, many of the principles are equally applicable to the weighing of bulk liquids. For the sake of convenience, we have classified bulk material weighing into three general types:

Custody Transfer

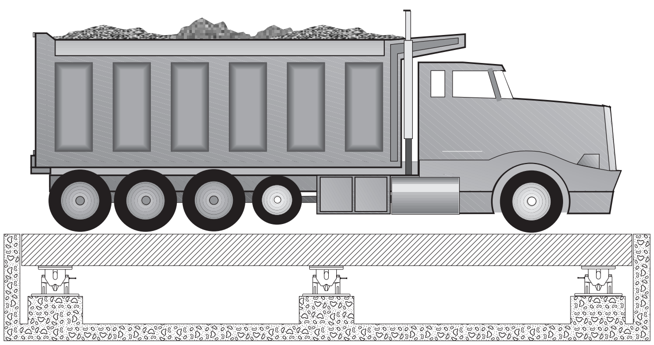


Figure 1-1

Weighing bulk material on a truck scale is a typical example of custody transfer weighing where material is being traded for dollars. The filled truck is weighed and the known tare weight of the truck is subtracted to determine the net weight of product. This may be done for invoicing or inventory-control purposes. Typically, achieving a predetermined weight is not important in this situation. What is important is knowing how much material entered or left the facility.

Material Proportioning

Figure 1-2 shows various ingredients being weighed on separate scales, then mixed. Each scale must be accurate, or there could be a detrimental effect on the proportions of each ingredient in the finished product.

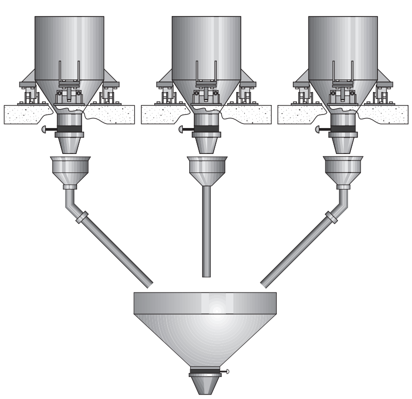


Figure 1-2

Figure 1-3 shows several materials being mixed to a given recipe and batched one at a time into a single weigh hopper. As all ingredients are weighed in the same weigh hopper, the weighing system must be linear to achieve correct proportioning. It does not need to be calibrated accurately if the final net weight of product is not critical.

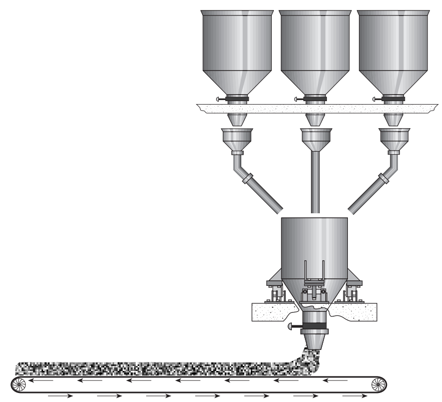


Figure 1-3

Loss in Weight

Figure 1-4 shows a situation where the weigh hopper is first topped up and when the filling process stops, the material is fed out at a controlled rate. The total amount of material supplied to the process may be important, but the rate at which product is fed into the batching process from the weigh hopper is usually more important.

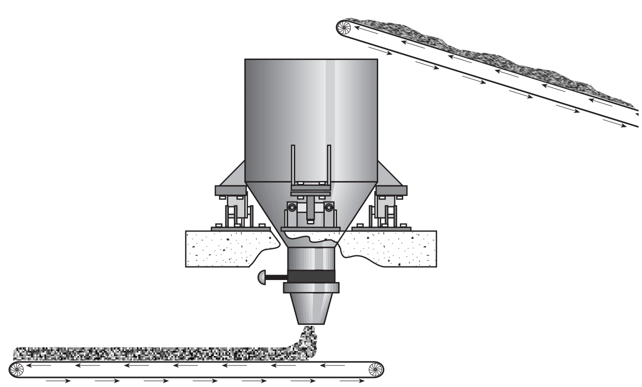


Figure 1-4

Common Hopper Scale Arrangements

A. One of the simplest hopper weighing systems is illustrated below in Figure 1-5. The weigh hopper may be filled using a feed conveyor, front-end loader, auger, etc., and the material may be removed from the hopper using a discharge conveyor.

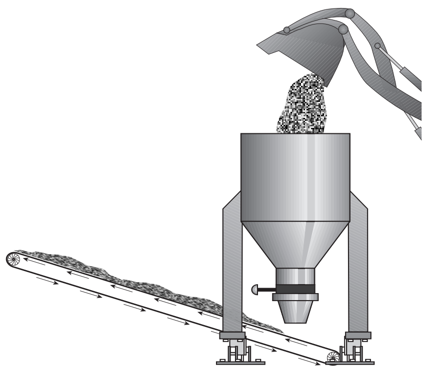


Figure 1-5

Advantages of this system are:

- Low cost compared to other systems.
- Low overall height.

Disadvantages of this system are:

- Slow fill and discharge (low throughput).
- Difficult to achieve an accurate prescribed weight because of inconsistency in input material flow.

B. Figure 1-6 below illustrates a weigh hopper positioned directly under the storage silo.

Advantages of this system are:

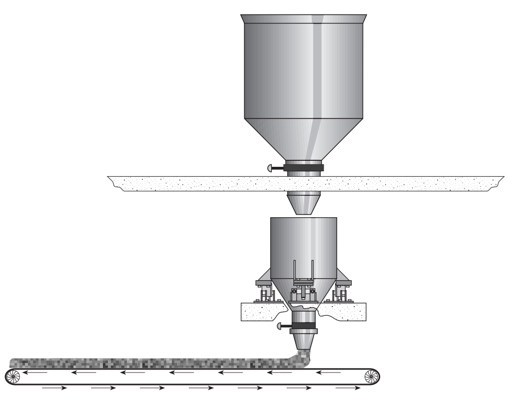


Figure 1-6

- The weigh hopper is gravity-fed, simplifying the feed process and providing a more uniform flow.
- Faster fill cycle and hence greater throughput.
- 2-speed fill may be used for greater target accuracy.

Disadvantages of this system are:

- Higher overall height.
- Material must be conveyed higher to storage silo.

C. A conveyor-fed system can be improved by adding an upper surge hopper as shown in Figure 1-7. The surge hopper allows the conveyor to be run continuously and isolates the weigh hopper from the sometimes erratic flow of material from the conveyor.

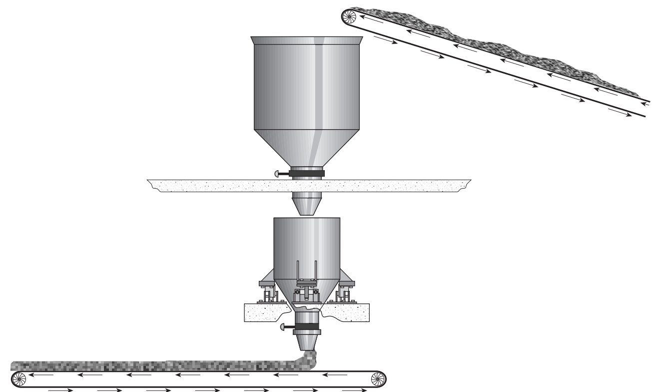


Figure 1-7

Advantages of this system are:

- Weigh hopper isolated from the feed conveyor.
- The input conveyor can run continuously.
- Surge hopper serves as a buffer to smooth out demand.
- 2-speed fill is possible.
- Faster fill and higher throughput possible.

Disadvantages of this system are:

- Higher overall height.
- Higher cost.
- More complex controls and mechanical arrangement.

D. This arrangement is similar to Example C, however, a lower surge hopper has been added to speed up the discharge cycle. This system, shown in Figure 1-8, is typically used in multi-draft grain loadout systems where multiple drafts are required to fill a rail car or barge. The weight of each draft can be accumulated and the target weight of the final draft adjusted to achieve the desired car net load.

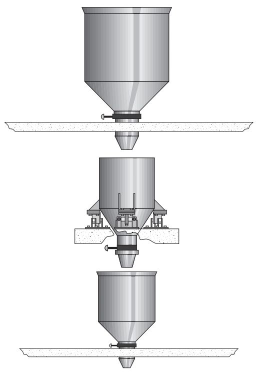


Figure 1-8

Advantages of this system are:

- Weigh hopper isolated from feed conveyor.
- Surge hopper serves as a buffer to smooth out demand.
- 2-speed fill is possible.
- Faster fill, discharge, and throughput possible.

Disadvantages of this system are:

- Higher overall height.
- Higher cost.
- More complex controls and mechanical arrangement.

The systems described up to this point deliver a single material in pulses rather than from a continuous flow. They may be used for in-plant process weighing or custody transfer. Figures 1-9 and 1-10, described below, provide a continuous material flow and are more often used for process weighing.

E. Figure 1-9 illustrates a single storage silo with two weigh hoppers suspended underneath. This arrangement can be used to provide material continuously to a process. As one hopper is emptying, the other can be filling If the system is sized correctly, there is no interruption to the material flow on the discharge belt.

Advantages of this system are:

- Continuous material flow.
- High throughput possible.

Disadvantages of this system are:

- Higher overall height.
- Higher cost than pulse discharge systems.
- More complex controls and mechanical arrangement.

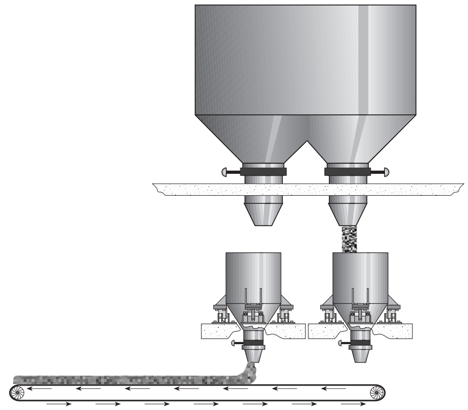


Figure 1-9

F. Figure 1-10 illustrates a loss in weight system. This is used where a process needs a batch of material (not more than the capacity of the weigh hopper), but that material needs to be fed to the process at a controlled rate.

The process starts by filling the hopper with at least enough material for the upcoming process. The fill is then stopped and the discharge commences. The rate at which the discharge takes place is controlled by monitoring the “loss in weight” of the hopper and then modulating the discharge rates to maintain the desired flow rate. The discharge may be ended at the completion of the process step, or when a specific amount of material has been discharged.

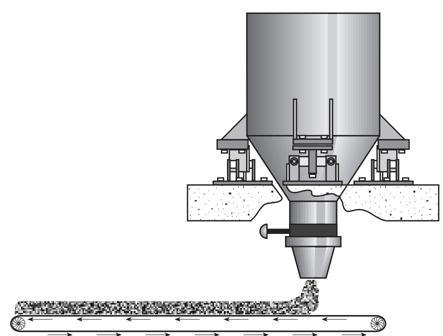


Figure 1-10

Advantages of this system are:

- Gives the ability to supply material at a constant rate

Disadvantages of this system are:

- Complex controls and mechanical arrangement
- Higher cost than pulse discharge systems.

G. Figure 1-11 illustrates a multiple-ingredient batching system where all the ingredients are weighed one at a time in a single weigh hopper.

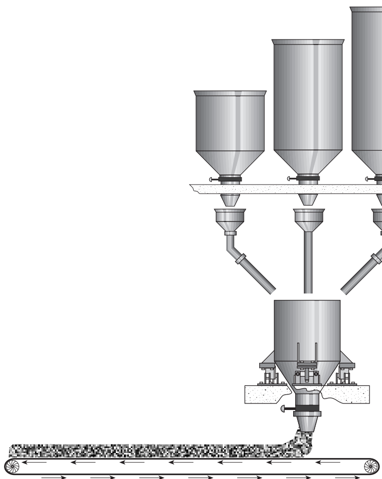


Figure 1-11

Advantages of this system are:

- Lower cost than multiple-weigh hoppers
- Scale calibration may not be critical, as all ingredients are weighed in a single scale, assuring correct proportions.

Disadvantages of this system are:

- The accuracy of minor ingredients may suffer where the scale capacity is large compared to the weight of ingredient.
- System is somewhat slow because each material must be batched in one at a time, and the cycle cannot repeat until the weigh hopper has been discharged.

Note: We recommend that you do not attempt to weigh a batch of material which is less than 20 scale divisions since the accuracy will be questionable.

For example, if a hopper scale has a .5 lb division size, we recommend that you not weigh less than a 10-lb batch on that scale. It's better to weigh minor ingredients accurately on a scale suited to the purpose, and add those ingredients to the batch by hand. For example, if making raisin oatmeal cookies, it may not be too much of a problem to batch-weigh the raisins along with the oatmeal. However, it may be prudent to weigh the salt on a more sensitive bench scale and hand-add it to the hopper at completion of the weigh cycle.

H. The system illustrated in Figure 1-12 below is a multi-ingredient batching system which has a separate weigh hopper for each ingredient.

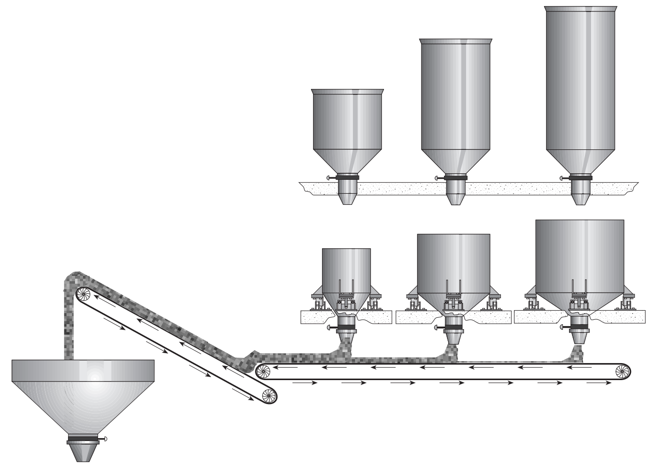


Figure 1-12

Advantages of this system are:

- Weigh hopper capacity can be sized appropriately for each material so that each weighment is close to the scale capacity, providing greater accuracy.
- Faster throughput, since all materials can be weighed and discharged simultaneously.

Disadvantages of this system are:

- Higher cost.
- Each scale must be accurate to ensure correct proportioning.

Load Introduction Principles

A clear understanding of the exact manner in which a load must be placed on a load cell will assist you in both designing a vessel that is to be equipped with load cells, and in choosing the correct type of load cells and mounts for your application.

The Ideal...

Load cell specifications are derived under laboratory conditions, where load is applied to the cell under near-perfect conditions. The performance of load cells in an actual process weighing application can be greatly degraded if care is not taken in the means by which the load is applied to the cell.

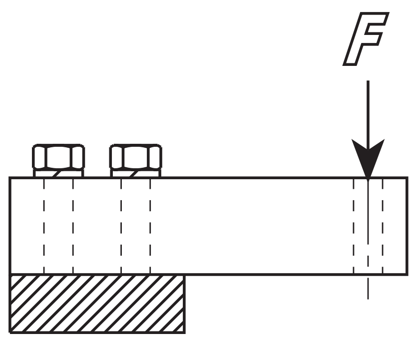


Figure 1-13

Figure 1-13 shows a typical mounting arrangement for a single-ended beam. The fixed end is fastened to a “rigid” foundation, while the free end is cantilevered to allow downward deflection as load (F) is applied. Under ideal conditions, the mounting surface would be flat, horizontal and perfectly rigid. The load F would be introduced vertically with minimal extraneous forces applied, and the load cell would be totally insensitive to all forces other than precisely vertical ones.

However, in the real world, load cell mounting and loading conditions are far from ideal. Incorrect loading is by far the most common cause of accuracy problems encountered by service technicians. Understanding the following common load introduction problems will prevent loading errors in your vessel weighing application.

Though the discussion is confined to single-ended beams, many of the principles apply equally to other load cell types.

Angular Loading

This is a condition where the load F is introduced through the loading hole, but at an angle to its center line. This angular force can be broken up into its vertical component along the loading hole center line which the cell will register and its horizontal component at 90° from the center line. This horizontal component is a side force to which, ideally, the load cell would be totally insensitive. For example, if force F is inclined to the load hole center line at an angle of 5°, then the force registered by the cell is reduced by .4% while a side force of .01F is also applied.

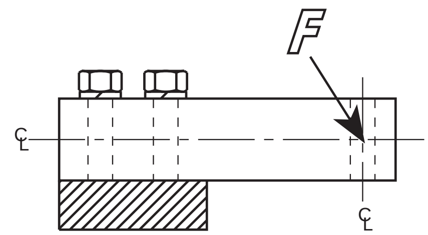


Figure 1-14

If the direction of the force is constant, calibration will compensate for this and the scale will weigh accurately. However, if the angle changes as the force is applied, it will cause nonlinearity and if there is friction in the mechanical system, hysteresis will also be present. Angular loads can be caused by mounts that are out of level, a nonrigid foundation, thermal expansion/contraction, structure deflection under load, and the unavoidable deflection of the load cell itself.

Eccentric Loading

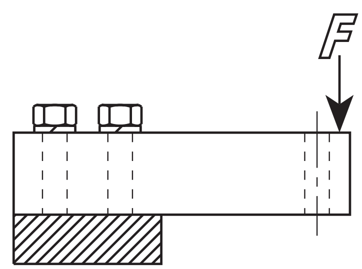


Figure 1-15

This is a condition where the force F is applied vertically to the cell, but its line of action is shifted away from the vertical line through the loading hole. This is not a detrimental condition if the force is applied consistently at the same point, since calibration will compensate for this effect. However, if the point of application moves horizontally as the scale is loaded, it will cause nonlinearity and possibly hysteresis. Eccentric loads may be caused by poorly-designed mounting arrangements and thermal expansion/contraction of the scale.

Side Loading

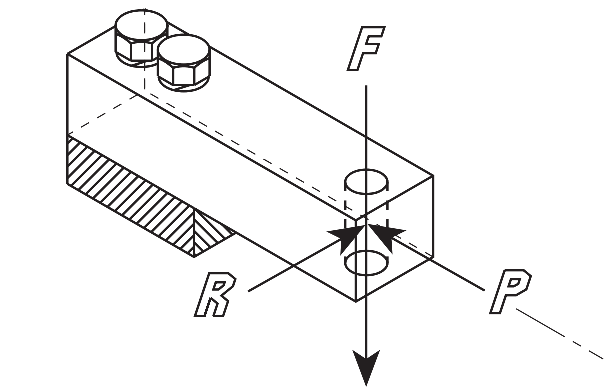


Figure 1-16

This is a condition where the vertical force F (which you are trying to measure) is accompanied by a side force R applied at 90° to F. This force can be constant, but more typically is a force that varies over time and hence affects the linearity and possibly the hysteresis of the scale. The ideal load cell would be totally insensitive to side loads. However, in practice these extraneous forces do affect the output of the cell and two seemingly identical cells can react differently to the same side load. A related condition is the END FORCE, P, which is similar to a side force, except that it acts on the end face of the cell. Side forces are the result, typically, of thermal expansion/contraction, mounts which are not level, and vessel dynamics (caused by mixers, etc.).

Twisting Loads

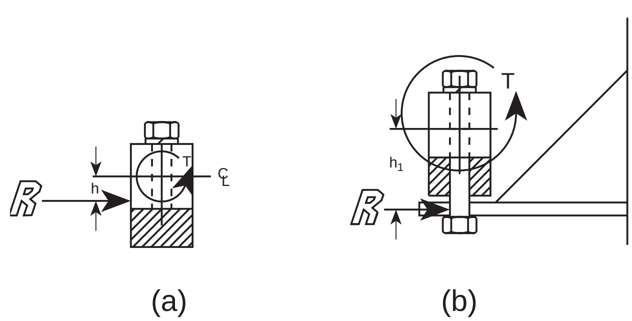


Figure 1-17

Typically, a side force does not act exactly at the neutral axis and hence produces a torque or twisting effect in addition to the side force. A load cell can be subjected to a torque (T) in a number of ways. Figure 1-17 (a) illustrates a condition where the line of action of a side force is moved away from the neutral axis by a distance h resulting in a torque of Rh. Figure 1-17 (b) illustrates a situation where the load is hung from the cell using a bolt. Any side force applied by this arrangement has a much larger twisting effect on the cell because of the increased distance h_1 to the neutral axis.

Figure 1-18 illustrates a torque of magnitude F_y exerted as the result of the load F being applied at a distance y from the loading hole center line.

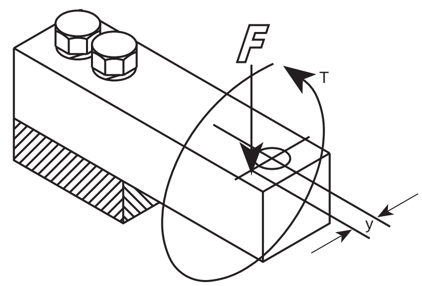


Figure 1-18

Mounts which are out of level, thermal expansion/contraction, structure deflection under load and dynamic side forces (caused by rotating mixers, etc.) all cause twisting of the load cell. Since these forces tend to vary in magnitude as a function of time, temperature and/or load, the effects are not predictable, and will degrade system accuracy.

Maximizing System Accuracy

High-accuracy systems are generally considered to have system errors of ±.25% or less; lower accuracy systems will have system errors of ±.50% or greater. Most weight indicators typically have an error of ±.01%, hence, the main source of error will be the load cells and, more importantly, the mechanical arrangement of the scale itself. In vessel weighing, each installation is unique in terms of the mechanical arrangement, site conditions and environmental factors. Therefore, it is impossible to be specific in this publication about the system accuracy that can be achieved. The first requirement is to determine what the customer's accuracy expectations/requirements are, then design the system accordingly. Grouped under various subheadings below are various recommendations that contribute to high accuracy. It will not be possible to comply with all these recommendations; however, they should be kept in mind when designing a system.

Environmental

- Install the vessel in a controlled environment where seasonal temperature fluctuations are minimized. If this is not feasible, use load cells with temperature compensation specifications that will allow satisfactory performance over the expected temperature range.
- Use a metal shield to protect the load cells from radiant heat sources. Use an insulating pad between the vessel and load cell mount if heat is being conducted.
- If thermal expansion/contraction of the vessel is expected, choose a mount which will allow unhindered lateral movement. If stay rods are required, position them so that thermally-induced movement is minimized. See *Vessel Restraint Systems* in Section 3 for more information.
- Place the vessel indoors, if possible, where it will be protected from wind and drafts.
- Do not place the vessel in an environment where its support structure is subject to vibration. Ensure that vibrations are not transmitted via attached piping or stay rods.
- Select load cells and mounts that will give the degree of corrosion protection required.
- Use load cells that have the degree of environmental protection required for the application. For example, avoid possible drifting problems with standard load cells in washdown applications by specifying hermetically-sealed cells.

Load Cell and Mount

- Choose load cells whose accuracy is consistent with the desired system accuracy.
- Do not grossly oversize the load cells; see *Load Cell Capacity* on page 1-9. Best accuracy will be achieved when weighing loads close to the vessel capacity. As a general rule, do not attempt to weigh a load of less than 20 graduations.
- If it is not possible to trim the corners, use load cells with matched outputs, particularly if the vessel is not symmetrical and/or the material is not self-leveling. Otherwise, use a pretrimmed junction box.
- Support the vessel entirely on load cells; do not use dummy cells or flexures that would hinder a good calibration. See *Partial Mounting on Flexures* on page 3-11.
- Use proven load cell mounts that will provide optimal loading conditions.
- Orient the mounts as recommended in the installation manual.

Mechanical/Structural

- Support the load cell mounts on a rigid structure; this will ensure a high natural frequency and reduce the amount of bounce and instability. All support points must be equally rigid to avoid tipping of the vessel as load is applied. Minimize interaction between adjacent weigh vessels mounted on the same structure. Vehicular traffic must not cause deflection of the vessel's support structure.
- Ladders, pipes and check rods, etc. should not be allowed to shunt the weight that should rest on the load cells.
- Where piping or conduit must be attached to the vessel, use the smallest diameter acceptable for the application. Use the longest unsupported horizontal length of pipe possible to connect to the vessel.
- Use an indicator that is EMI/RFI protected. Provide grounding and transient protection in accordance with the manufacturer's recommendations. In general, take measures to reduce electrical interference.
- Use a good-quality junction box which remains stable with changing temperatures. Look for a junction board which has a solder mask at a minimum and which preferably is conformally coated also. Ensure that the enclosure is suited to the environment.

Calibration

- Design in a convenient means of hanging weight from the corners of the vessel to trim the load cell outputs and for calibration. Use weights as described above, or known weight of material to perform the calibration. See *Calibrating Vessel Weighing Systems* in Section 4.

Operational Considerations

- Maintain an even and consistent flow of material.
- Avoid simultaneous fill/discharge of weigh vessel.
- Slow down the filling cycle as much as possible and/or use a 2-speed fill cycle.
- Reduce to a minimum the amount of "in flight" material.
- Use preact learning to predict the optimum cutoff point based on past performance.
- Use Auto Jog to top off contents after fill.
- If possible, switch off any vibrating or mixing equipment while the weight is being determined.
- Reduce to a minimum the surging of liquids while a weight reading is being taken.

Selecting Number of Supports & Load Cell Capacity

Number of Supports

The number of supports to be recommended is dependent on the geometry, gross weight, structural strength and stability of the vessel. The number of supports chosen for a vessel obviously influences the capacity of the load cells required. In general, no more than eight supports should be used. It becomes more difficult to get even weight distribution on all supports as the number increases beyond three. Below is a look at a number of examples.

Suspended Vessels

These vessels are very often suspended from an existing structure which will sometimes dictate how many supports will be used. In general, one or more supports may be used. Using three supports or fewer has the advantage of not requiring adjustment of the length of the support linkages to distribute the load equally between all supports (assuming the cells are arranged symmetrically on the vessel).

Upright cylindrical vessels in compression

The most convenient method of mounting is with three supports arranged at 120° degree intervals. Correct weight distribution is inherent to 3-point support and is preferred whenever possible. With tall slender vessels or vessels subject to fluid sloshing, wind or seismic loads, stability against tipping becomes a consideration. In these situations, four or more supports should be considered. See Appendix section on wind and seismic effects.

Square, rectangular or horizontal cylindrical vessels mounted in compression

Because of geometry, it is usually most convenient to mount these vessels on four supports, close to each corner. Higher capacities may, of course, require more than four.

Load Cell Capacity

It is vital to the performance of a weighing system to select load cells of the correct capacity. Here are some guidelines:

- All load cells selected must be of the same capacity.
- Estimate the vessel dead weight, including all piping, pumps, agitators, insulation and vessel heating fluids.
- Add the maximum live weight of product to be weighed to the dead weight. This is the gross weight of the vessel and contents.
- Divide the gross weight by the number of legs or support points. This is the nominal weight which will be carried by each load cell.
- Select a load cell with a capacity somewhat greater than the nominal weight. The following should be considered when determining how much greater the load cell capacity should be:

  1. Is your dead weight accurate?
  2. Will the load be evenly distributed on all cells?
  3. Is the vessel fitted with an agitator or subjected to shock loading?
  4. Is it possible the vessel will be overfilled, exceeding your live weight value?
  5. Will the vessel be subjected to wind or seismic loading? For more information, see *Wind and Seismic Effects on Vessel Stability*.

A good rule of thumb is to select a load cell with a capacity 50 – 100% in excess of the calculated nominal load per cell. Once the load cell capacity has been determined, check that the live weight signal is adequate for the instrumentation selected; see Section 4 for information on how to determine the microvolt-per-graduation for your system. This is particularly important when the ratio of dead weight to live weight is high.

- Additional factors to consider:

  Load Cell Construction Material — In a corrosive environment, stainless steel outperforms nickel-plated alloy steel.

  Load Cell Protection — The ultimate degree of protection can be achieved with hermetically-sealed load cells which ensure the integrity of the strain gauge section of the cell in corrosive or washdown applications.

  Cable Length — Check that the standard cable length will be adequate for your installation. Longer cable lengths are available on special order.

- See page 2-22 for compatibility information on mounts and load cells by capacity. Capacity requirements may limit practical applications of many models.

Choosing the Correct Load Cell

Misuse of any product can cause major cost and safety problems; load cells are no exception. Unfortunately, the load cell protection rating systems used in the industry today are inadequate in some ways. That's why Rice Lake Weighing Systems, with years of load cell experience, has developed its own rating system for load cells. Our system categorizes load cells in two major groups: hermetically-sealed (HS), and environmentally-protected (EP). Hermetically-sealed cells are then further characterized by IP (International Protection) numbers. We feel this system effectively matches load cell to application for optimal results.

To choose the proper load cell protection qualities, a fundamental understanding of the differences between "environmentally-protected" and "hermetically-sealed" load cells is necessary. The inappropriate use of environmentally-protected load cells in harsh conditions is a prescription for load cell failure. Because of the extra manufacturing steps, hermetically-sealed load cells cost more than environmentally-protected versions. Despite the higher initial cost, hermetically-sealed load cells may be the best long-term choice for harsh chemical, washdown, and unprotected outdoor applications.

Environmentally Protected

Environmentally-protected load cells are designed for "normal" environmental factors encountered in indoor or protected outdoor weighing applications. By far the most popular type, these load cells may employ strategies like potting, rubber booting, or redundant sealing to afford some protection from moisture infiltration.

Potted load cells utilize one of several types of industrial potting materials. The liquid potting material fills the strain gauge cavity then gels, completely covering the strain gauge and wiring surfaces. While this may significantly diminish the chance of moisture contamination, it does not guarantee extended waterproof performance, nor does it withstand corrosive attack.

A second method of protection uses an adhesive foam-backed plate. This protection affords some moisture and foreign object protection, but less than potted cells. In many cases, manufacturers will use a caulking material to seal the plate to decrease the potential for cavity contamination. A common approach among manufacturers to further decrease the entry of moisture to the strain gauge combines both a potted cavity and a foam-backed plate, in a process called redundant sealing.

Yet another strain gauge cavity protection strategy is the rubber boot. Commonly employed with cantilever and bending beam models, the boot covers the cavity and is secured by clamps. While this provides easy access for repairs, the boot may crack if not lubricated regularly, allowing contaminants into the load cell cavity. Lubricating the rubber boot during routine inspections will contribute to the long-term durability of the load cell.

Protecting the strain gauge cavity is just one consideration in protecting a load cell from contamination. Another susceptible area is the cable entry into the body of the load cell. Most environmentally-protected load cells incorporate an "O" ring and cable compression fitting to seal the entry area. This design provides protection *only* in applications with minimal moisture. In high-moisture areas, it is safest to install all cabling in conduit, providing both a moisture barrier and mechanical protection.

Although environmentally-protected load cells keep out unwanted contaminants, they are not suited for high moisture, steam, or direct washdown applications. The only long-term strategy for these applications is to use true hermetically-sealed load cells.

Hermetically Sealed

Hermetically-sealed load cells offer the best protection available for the weighing market. Using advanced welding techniques and ultra-thin metal seals, these load cells handle the extremes of harsh chemical and washdown applications. What makes the seal unique is the process of laser-welding metal covers to protect the strain gauge and compensation chambers. The cavities are then injected with potting or, in the case of glass-to-metal seals, filled with a pressurized inert gas, providing a redundant seal. As a final assurance of the integrity of the seal, a leak test is conducted to reveal any microscopic flaws in the sealing weld.

True hermetic protection addresses both the strain gauge cavity and cable entry area. The most advanced cable entry design employs a unique glass-to-metal bonding seal which makes the cable termination area impervious to moisture. Cable wires terminate at the point of connection to the load cell, where they are soldered to hermetically-sealed pins that carry signals to the sealed strain gauge area through a glass-to-metal seal. Water or other contaminants cannot "wick up" into the load cell, since the cable ends at the entry point. This design allows for field-replaceable cable, since the connection is outside the load cell.

A word of caution: stainless steel load cells are not synonymous with hermetically-sealed load cells. While *environmentally-protected* stainless steel load cells may be suitable for dry chemical corrosive environments, *hermetically-sealed* stainless steel models are the appropriate choice for high moisture or washdown applications.

International Protection (IP) Rating Guide

If a hermetically-sealed cell is necessary, further classification is needed to be sure of the type of protection a particular cell offers. For hermetically-sealed cells, Rice Lake Weighing Systems uses the International Protection (IP) rating system. We find the IP numbers and their definitions are suitable for the classification of hermetically-sealed load cells, and only apply IP numbers to such cells. The IP numbers on a hermetically-sealed cell further specify the treatment a specific cell can endure in environments more severe than simple washdown. The following tables define the IP numbers alone and in conjunction with the hermetically-sealed rating.

Example: Protection level offered by an IP67 rated product **IP 67**

Protection against solid objects

First number (in this case 6)

- **0** No protection
- **1** Protected from solid objects up to 50 mm (e.g., accidental touch by hands)
- **2** Protected from solid objects up to 12 mm (e.g., fingers)
- **3** Protected from solid objects more than 2.5 mm (e.g., tools and small wires)
- **4** Protected from solid objects more than 1 mm (e.g., small wires)
- **5** Protected from dust; limited entrance (no harmful deposit)
- **6** Totally protected from dust

Protection against liquids

Second number (in this case 7)

- **0** No protection
- **1** Protected from vertically-falling drops of water (e.g., condensation)
- **2** Protected from direct sprays of water up to 15° from vertical
- **3** Protected from direct sprays of water up to 60° from vertical
- **4** Protected from water sprayed from all directions; limited entrance allowed
- **5** Protected from low pressure jets of water from all directions; limited entrance allowed
- **6** Protected from strong jets of water (e.g., for use on ship decks); limited entrance allowed
- **7** Protected from the effects of immersion between 15cm and 1m
- **8** Protected from extended periods of immersion under pressure

IP Numbers with Hermetically Sealed (HS) or Environmentally Protected (EP) Ratings

Rating	Protection
EP	Dust proof, not protected from moisture or water
HS-IP65	Dust proof, protected from splashes and low-pressure jets
HS-IP66	Dust proof, protected from strong water jets
HS-IP67	Dust proof, protected from temporary immersion in water 1 meter deep for 30 minutes
HS-IP68	Dust proof, protected from continuous immersion in water under more severe conditions than IP67
HS-IP66/68	Dust proof, protected from strong water jets and/or constant immersion

Manufacturers may give a NEMA rating to cells. This system was established for electrical enclosures and is difficult to apply to load cells. However, if you see a NEMA rating and need a general idea of what it means, IP67 and NEMA 6 cells are comparable and meet similar requirements.

Time invested in a well-considered choice offers large returns in the long run. If there is any doubt as to which cell to use, consult with a company such as Rice Lake Weighing Systems that offers experience and knowledge with every load cell.

Calculating Thermal Expansion of Vessels & Stay Rods

Stay Rod Expansion/Contraction

Stay rods attached to vessels subjected to thermal changes can introduce significant forces which affect system accuracy. The method of attachment and the length of the stay rods directly affect these forces.

Figure 1-19 illustrates a stay rod rigidly attached to a bracket on each end—one bracket is rigidly mounted, the other is unattached, thus allowing the rod to expand and contract freely. As the temperature rises or drops, the length of the rod will increase or decrease respectively. The change in length (ΔL) is proportional to the original length (L), the change in temperature (ΔT), and the coefficient of linear expansion (a) which is a characteristic of the rod material.

ΔL can be calculated from the following equation:

$$\Delta L = a \times L \times \Delta T$$

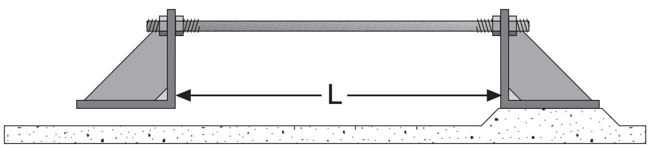


Figure 1-19

Table 1-1 below lists the coefficient of thermal expansion (α) for various materials used to construct vessels and stay rods.

Example:

If the rod in Figure 1-19 is made from 1018 steel, then $a = 6.5 \times 10^{-6}$ from Table 1-1. If the rod is 48" long and the temperature increases by 60°F, the length of the rod will increase by:

$$\Delta L = a \times L \times \Delta T$$

$$\Delta L = 6.5 \times 10^{-6} \times 48" \times 60$$

$$\Delta L = .019$$

Material		Coefficient of Linear Expansion (inches per °F)
Steel	Low carbon (1018)	6.5×10^{-6}
Stainless steel	302	9.6×10^{-6}
	303	
	304	
	316	8.9×10^{-6}
Aluminum	6061	13.0×10^{-6}

Table 1-1

This shows that a 48" steel rod will increase by .019" as a result of a 60°F temperature rise. This may seem insignificant, until you consider the forces which can result if the stay rod is confined rigidly at each end, as in Figure 1-20.

In Figure 1-20, a 1" steel rod 48" long is attached to a bracket on each end, and both brackets are rigidly attached. If the rod is initially adjusted so that there is no strain, a subsequent 60°F rise in temperature will cause the rod to exert a force of 9,000 lb on each bracket. Hence, vessel restraint systems must be designed and installed properly so that they don't move and/or apply large lateral forces to the weigh vessel.

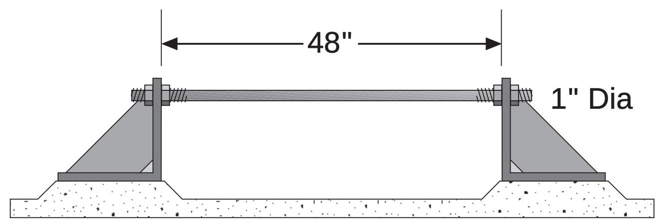


Figure 1-20

Vessel Expansion/Contraction

Temperature fluctuations will cause weigh vessels to grow and contract. Figure 1-21 on the following page best illustrates this.

Shown is a top view of a rectangular vessel. The solid line represents its size at 70°F and the inner and outer broken lines represent its size at 40°F and 100°F respectively. The amount that the sides will increase/decrease in length can be found using the expansion formula discussed previously.

Therefore: $\Delta L = X \times L \times \Delta T$

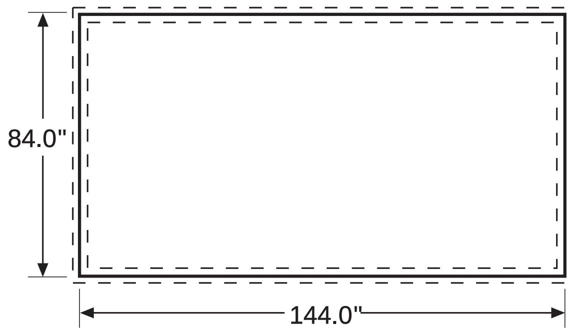


Figure 1-21

If the vessel is made from mild steel, the length will vary by ± .028" ($6.5 \times 10^{-6} \times 144 \times 30$), and the width will vary by ± .016" ($6.5 \times 10^{-6} \times 84 \times 30$) as the temperature fluctuates by ± 30°F. It will be apparent that if the load cell is held rigidly by the mount, enormous side forces will be applied to the cell, hence the need to use a mount which can accommodate vessel expansion/contraction due to changes in temperature.

In the case of a cylindrical vessel, the change in diameter (ΔD) resulting from a change in temperature (ΔT) is given by:

$$\Delta D = a \times D \times \Delta T$$

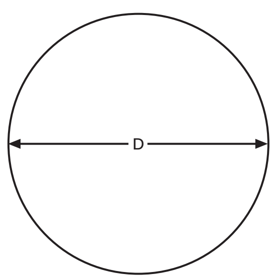


Figure 1-22

Example:

> If a cylindrical vessel is 96" in diameter and made from 304 stainless steel and is subjected to a temperature rise of 80°F as the result of being filled with a hot liquid, then the diameter will increase by:

$$\Delta D = 9.6 \times 10^{-6} \times 96 \times 80$$
$$= .074"$$

Vessels with attached piping can be subjected to severe side forces as a result of temperature variations if the connections are not executed properly. It is worth noting that vessels expand and contract vertically as well as horizontally with changes in temperature. Rigidly-attached piping may magnify the effects of this expansion, as seen in Figure 1-23. See *Attaching Piping to Weigh Vessels* in Section 3 for detailed guidelines on this subject.

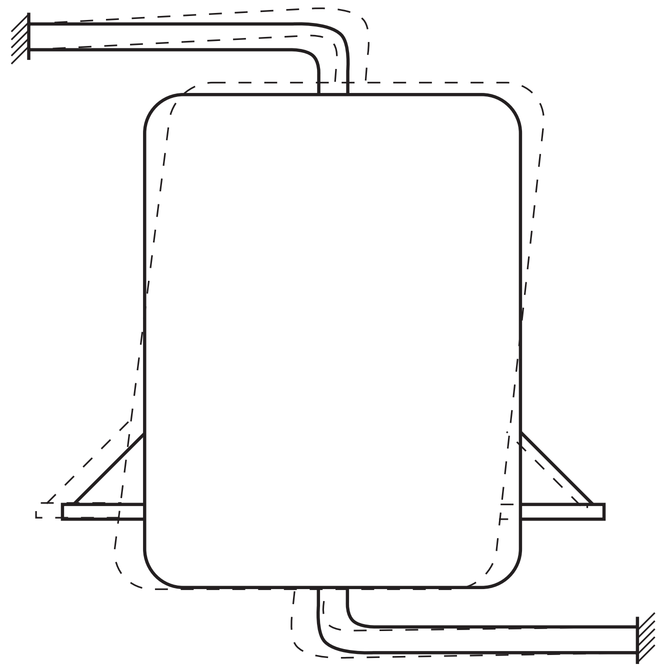


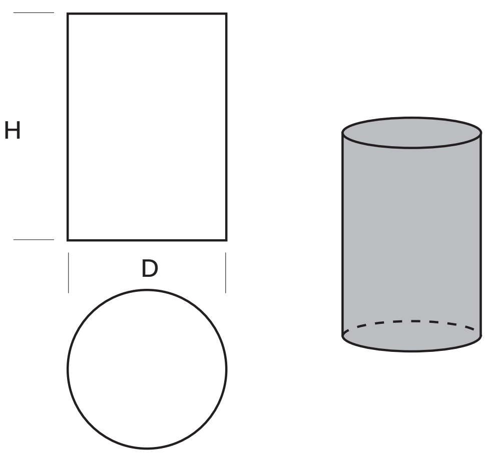
Figure 1-23

Calculating Tank Volumes

Formulas for Various Tank Shapes and Sections

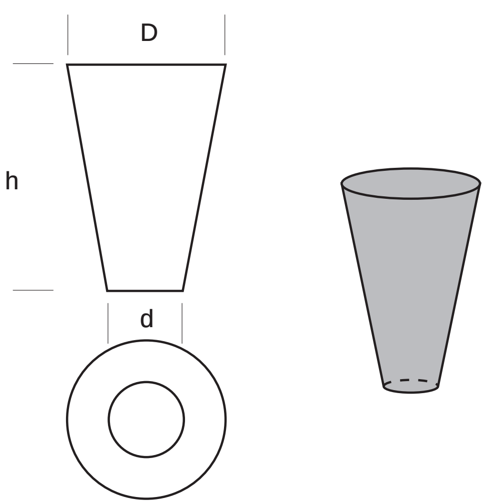
Cylinder

Volume = $\dfrac{\pi}{4} D^2 H$



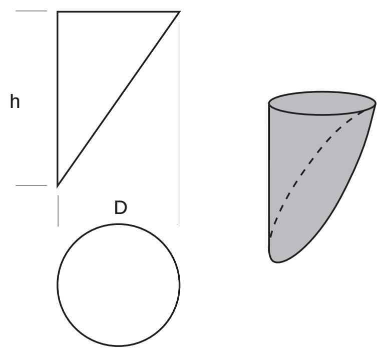
Frustum of Cone

Volume = $\dfrac{\pi}{12} h\left(D^2 + dD + d^2\right)$



Portion of Cylinder

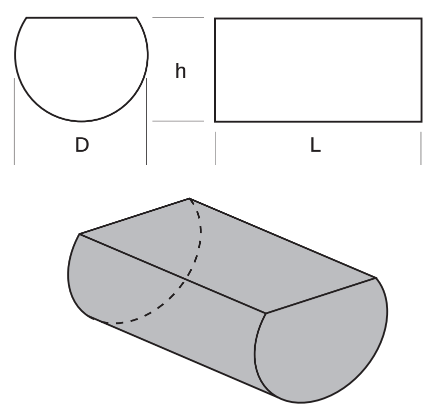
Volume = $\dfrac{\pi}{8} hD^2$



Horizontal Cylinder (Partially Filled)

Volume =

$$\frac{\pi}{4} D^2 L - \frac{\pi}{720} D^2 L \cos^{-1} \frac{(2h - D)}{D} + \left(h - \frac{D}{2}\right) L \sqrt{hD - h^2}$$



In the special cases where h=D (that is, the vessel is filled completely) then this formula reduces to:

Volume = $\dfrac{\pi}{4} D^2 L$

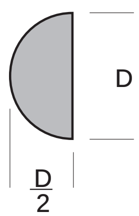
h = $\dfrac{D}{2}$ (that is, the vessel is filled half way) then this formula

reduces to:

Volume = $\dfrac{\pi}{8} D^2 L$

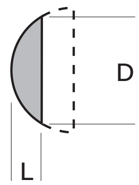
Hemispherical End

Volume = $\dfrac{\pi D^3}{12}$



Spherical Segment

Volume = $\pi L\left(\dfrac{D^2}{8}+\dfrac{L^2}{6}\right)$

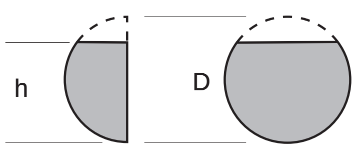


The radius of the sphere from which the segment is cut is r = $\dfrac{D^2+4L^2}{8L}$

Note: r $\neq \dfrac{D}{2}$ (D is the diameter of the vessel)

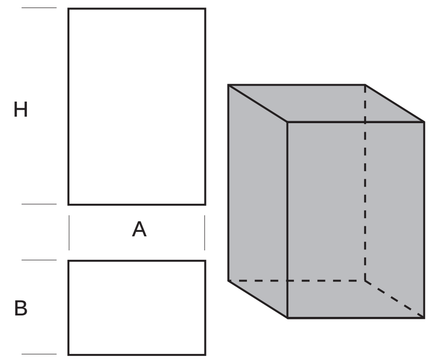
Hemispherical End (Partially Filled)

Volume = $\dfrac{\pi(3h^2D-2h^3)}{12}$



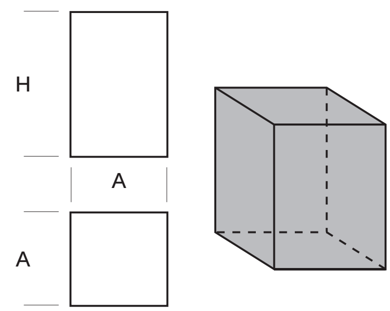
Square Prism
(Rectangular Cross Section)

Volume =ABH



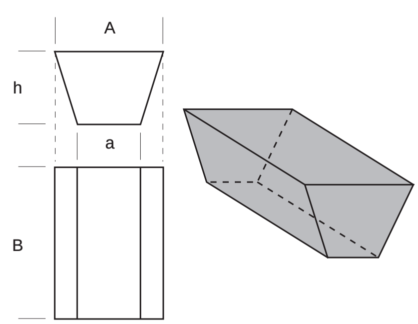
Square Prism (Square Cross Section)

Volume = A^2H



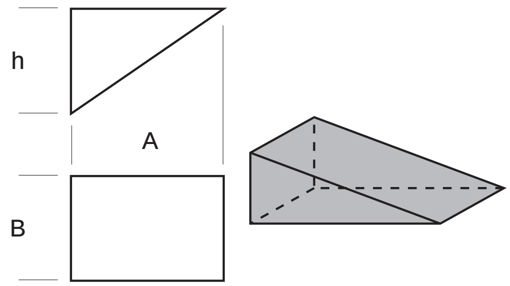
Wedge I

Volume = $\left(\dfrac{a+A}{2}\right)Bh$



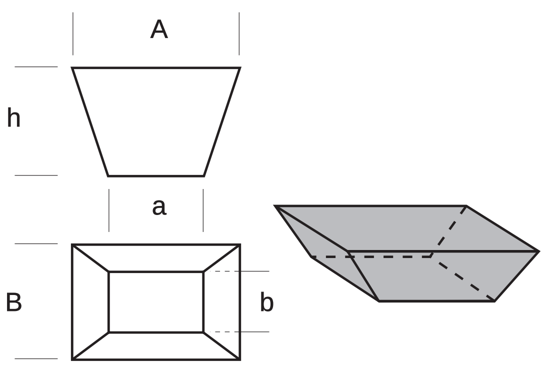
Wedge II

$$\text{Volume} = \frac{hAB}{2}$$



Frustum of Pyramid

$$\text{Volume} = \frac{h}{6}(2AB + Ab + aB + 2ab)$$



Angle of Repose

When a granular material is dropped from above onto a flat surface it tends to form a cone, as shown in Figure 1-24. The shape of this cone is described by the *angle of repose*, α, which is a characteristic of the material. The angle of repose varies somewhat with particle size, moisture content, etc. The relationship between α, h, and D (see Figure 1-24) is:

$$h = \frac{D\tan\alpha}{2}$$

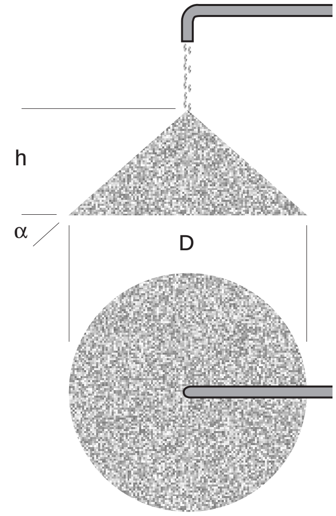


Figure 1-24

The volume of any cone is:

$$\frac{height}{3} \text{ x area of base}$$

In calculating the volume of material in a vessel, an adequate approximation can be made by adding 1/3 of the height of the cone to the height of material up to the cone.

For example, in Figure 1-25, assume the height of the material in the cylindrical vessel to be 15'+1.5'=16.5 feet.

Thus the volume is calculated using the following formula:

$$\text{Volume} = \frac{\pi}{4}D^2h = \frac{3.14}{4} \text{ x } (13)^2 \text{ x } 16.5 = 2190 \text{ cubic feet}$$

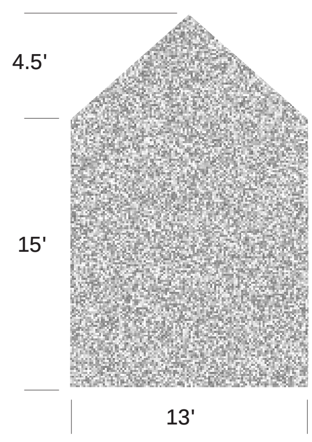
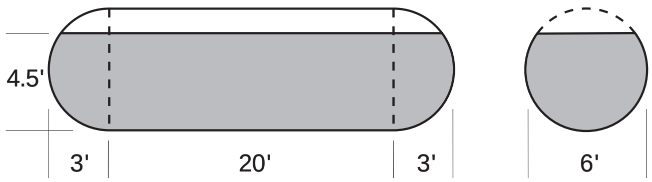


Figure 1-25

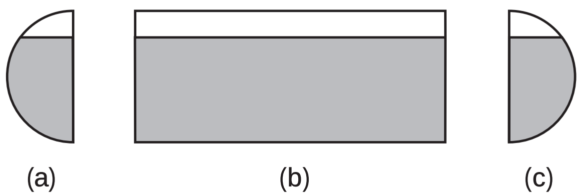
Calculation Examples

Example 1

Calculate the volume of liquid in the horizontal tank shown below. It has hemispherical ends and is filled to a height of 4.5 feet.



For ease of calculation, this can be broken into 3 sections



Step 1

The volume of section (a) or (c) is given by the formula:

$$\text{Volume} = \frac{\pi}{12}(3h^2D - 2h^3)$$

where $\pi = 3.14$, $h = 4.5$, $D = 6$

$$= \frac{3.14}{12}((3 \text{ x } 4.5^2 \text{ x } 6) - (2 \text{ x } 4.5^3))$$

$$= \frac{3.14}{12}(182.25)$$

$$= 47.7 \text{ cu ft}$$

Step 2

The volume of (b) is given by the formula:

$$\frac{\pi D^2 L}{4} - \frac{\pi}{720} D^2 L \cos^{-1}\left(\frac{2h - D}{D}\right) + \left(h - \frac{D}{2}\right) L\sqrt{hD - h^2}$$

where $\pi = 3.14$, $h = 4.5$, $D = 6$, $L = 20$

$$\frac{3.14 \text{ x } 6^2 \text{ x } 20}{4} - \frac{3.14 \text{ x } 6^2 \text{ x } 20\cos^{-1}}{720}\left(\frac{2 \text{ x } 4.5 - 6}{6}\right) + \left(4.5 - \frac{6}{2}\right)20\sqrt{4.5 \text{ x } 6 - 4.5^2}$$

$$= 565.2 - 3.14\cos^{-1}(.5) + 30\sqrt{6.75}$$

$$= 565.2 - 188.4 + 77.94$$

$$= 454.7 \text{ cu ft}$$

Step 3

Total Volume=Volume(a)+Volume (b)+Volume(c)

= 47.7 + 454.7 + 47.7

= 550.1 cu ft

Example 2

If, in the last example, the vessel were filled completely, then the volume would be:

Total Volume = Volume(a) + Volume(b) + Volume(c)

$$= \frac{\pi D^3}{12} + \frac{\pi D^2 L}{4} + \frac{\pi D^3}{12}$$

$$\frac{3.14(6^3)}{12} + \frac{3.14(6^2) \text{ x } 20}{4} + \frac{3.14(6^3)}{12} =$$

$$= 56.5 + 565.2 + 56.5$$

$$= 678.2 \text{ cu ft}$$

Example 3

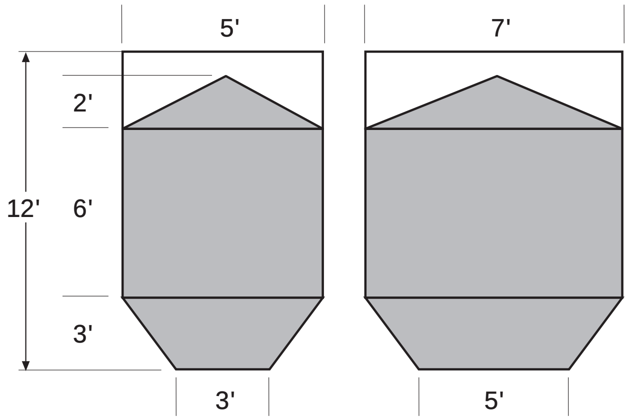
If the vessel in Example 2 is filled with linseed oil, calculate the weight of material when the vessel is full.

From the section *Density of Common Materials*, we know that the density of linseed oil is 58.5 lb/cu. ft. From Example 2, we know that the volume of the vessel is 678.2 cubic feet.

Weight of Material	=	Volume x Density
	=	678.2 x 58.5
	=	39,675 lb

Example 4

Calculate the volume of material in the hopper shown below.



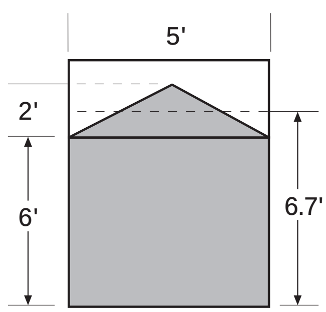
For ease of calculation, this may be broken into 2 sections as follows:

Step 1

The volume of section (a) is given by:

Volume $= ABh$

$= 5 \times 7 \times 6.7 = 234.5$ cu ft



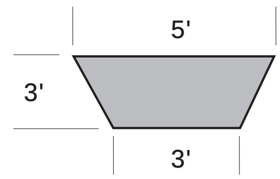
(a)

where the "leveled height" is assumed to be 6.7'.

Step 2

The volume of section (b) is given by:

$$\text{Volume} = \frac{h}{6}(2AB + Ab + aB + 2ab)$$



(b)

$= \frac{3}{6} \times ((2 \times 5 \times 7) + (5 \times 5) + (3 \times 7) + (2 \times 3 \times 5))$

$= \frac{3}{6} \times 146 = 73.0$ cu ft

Step 3

Total Volume=Volume (a) + Volume (b)

= 234.5 + 73.0

= 307.5 cu ft

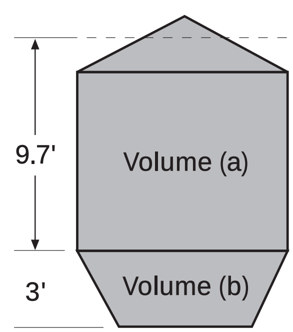
Example 5

If, in the last example, the vessel was filled to overflowing, then the volume would be :

Volume*(Total)* =Volume (a) + Volume (b)

Volume(b) is same as the previous example (73.0 cu ft)

Volume(a) = 5 x 7 x 9.7 = 339.5 cu ft



Volume*(Total)* = 339.5 + 73.0 = 412.5 cu ft

Densities of Common Materials

Material	Bulk Density lb/cu. ft.	Angle of Repose
Abrasive	150	
Abrasive Mix	153	
Acetylenogen	70-80	
Acid Phosphate	60	
Adipic Acid	45	
Alfalfa, ground	16	45
Alfalfa, seed	48	
Almonds, broken or whole	28-30	
Alum, pulverized	45-50	30-45
Alumina	60-120	30-45
Aluminate Gell	45	
Aluminum Chips	7-15	
Aluminum Etchant	54	
Aluminum Filament	74	
Aluminum Ore (Bauxite)	89-94	
Aluminum Powder	47-79	
Aluminum Sulfate	58-69	
Amianthus	20-40	
Ammonium Chloride	52	
Ammonium Nitrate	45-62	
Andalusite	49	
Antimony Oxide	45	
Apple Slices, dried	15	
Apple Pumice, dried	15	
Arsenic	30	
Arsenic Oxide	100-120	
Asbestos Fiber	19	
Asbestos Ore	81	
Asbestos Shorts	25	
Ashes, dry	35-40	45+
Asphalt, crushed	45	30-45
Bagasse	7-10	45+
Bakelite, powdered	30-40	
Barite	100-160	
Barium Carbonate	45-97	
Bark, wood	10-20	45+
Barley	38	up to 30
Basalt	184	
Batch, glass	90-100	
Bauxite, crushed	75-85	30-45
Beans, castor	36	up to 30
Beans, navy	48-54	up to 30
Beans, soy	45	up to 30
Beets	45	
Beet pulp	25-45	
Benzene Hexachloride	56	
Bicarbonate of Soda	41	
Binder 812	41	
Black Coloring	30	
Blood, ground	30	
Bluestone	60-70	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Bones, crushed	35-40	
Bones, ground	50	
Boneblack	20-25	
Bonechar	40	
Borax	60	
Borax, powdered	53	
Borton	75	
Bran	10-20	30-45
Brass, cast	519	
Brass, rolled	534	
Brewers grain, wet	55-60	45 & up
Brick, best pressed	150	
Brick, tire	137	
Brick, soft interior	100	
Bromoseltzer	37	
Bronze chips	30-50	
Bronze powder	75	
Cab O Sil	1	
Calcin flour	75-85	
Calcium Fluoride	82	
Calcium Lactate	26-29	
Calcium Phosphate	40-50	
Carbon activated	8-20	
Carbon, black pellet	25	up to 30
Carbon, black powdered	4-6	
Carbon lampback	7	
Carbon, masterbatch	40	
Carborundum	100	
Casem	38	
Caustic, soda	88	
Caustic, soda flakes	47	
Celation FP4	14	
Celite 535	9	
Cement Bulk	75-95	
Cement, clinker	75-85	30-40
Cement, portland	90	30-45
Cement, slurry	90-100	
Chalk, crushed	85-90	
Chalk, ground	70-75	
Chalk, lumpy	82-95	45 & up
Chalk, pulverized	70-75	
Charcoal	18-25	
Cherry wood	42	
Chickory	33	
Chili spice	45	
Chocolate powder	40	
Chrome ore	125-150	
Cinders, coal	40	25-40
Clay, ceramic, dry	65-80	
Clay, fire	40	
Clay	96	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Clay, potters	100-120	
Clay, product	36	
Clover, seed	48	
CMC Powder	52	
Coal Anthracite (solid)	94	
Coal Bituminous (loose)	43-50	30-45
Coal Char	24	
Coal, dust	35	
Coal, sized	50	
Cobalt Oxide	114	
Cocoa, beans	30-45	
Cocoa, flavoring	55	
Cocoa, powdered	33-35	
Coconut	20-22	
Coconut, shredded	20-25	45 & up
Coffee	20	
Coffee, fresh beans	30-40	30-45
Coffee, green beans	32-45	
Coffee, roasted bean	22-30	up to 30
Coffee, soluble	19	
Coke, calcined	35-45	
Coke, loose	23-32	30-45
Collupulin	19	
Compost	28	30-45
Concrete, sand & gravel	150	
Cookie Meal	38	
Copper, cast	542	
Copper, ore	120-150	30-45
Copper, sulfate	60-70	31
Copra	22-33	
Copra, cake ground	40-45	
Copra, meal	40-45	
Cork, granulate (1/2)	12-15	
Cork, granules	4	
Cork, solid	15	
Corn, cracked	40-50	
Corn, grits	40-45	30-45
Corn, meal	32-40	
Corn, seed	45	
Corn, shelled	45	up to 30
Cottonseed, cake	40-45	30-45
Cottonseed, flakes	20-25	
Cottonseed, meals	35-40	30-45
Cottonseed, meats	40	30-45
Cryolate (1/2)	90-110	30-45
Cryolite (100)	50-75	
Diatomaceous Earth	11-17	
Dracalcium Phosphate	40-50	
Disodium Phosphate	25-31	
Dolomite	83	
Dolomite, lumpy	90-100	30-45

Material	Bulk Density lb/cu. ft.	Angle of Repose
Dolomite, pulverized	46	
Donut Mix	45	
Earth	76	
Earth, common dry	70-80	30-45
Earth, moist	30-35	30-45
Ebonite	65-70	
Egg Yolk	23	
Elm, dry	35	
Feldspar (1/8)	100-160	
Feldspar, (1-100)	65-75	
Feldspar, ground	65-70	
Feldspar, lumps	85-95	34
Ferro Silicon	87	
Ferrous sulfate	50-75	
Fine, powder	127	
Fit	24-33	
Fish, scrap	40-50	
Flaxseed	43-45	
Flaxseed, meal	25	
Flaxseed, whole	45	up to 30
Flour	42-48	
Flour, wheat	35-40	45 & up
Flue, dust, dry	110-125	
Fluospar	82	
Fluospar, lumps	80-110	45 & up
Fluospar, solid	200	
Fly ash	61-95	
Fly ash, dry	35-40	
Foundry sand, loose	80-90	
Foundry sand, rammed	100-110	
Frodex 24	38	
Fullers Earth (burnt)	40	23
Galena	240-260	
Garbage	30	
Geon Resin	22	
Gilsonite	37	
Glass, broken	80-100	
Glass, frits	128	
Glass (window and plate)	161	
Glue	52	
Glue, ground	40	
Glue, pearl	40	
Gluten meal	40	30-45
Gold powder	53	
Granite, lumps	96	30-45
Granite, solid	150-170	30-45
Granular material	48	
Graphite, flake	40	
Graphite, ore	65-75	
Grape pomace	15-20	
Grass, seed	10-12	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Gravel, dry	90-100	30-45
Green powder	57	
Green stone	107	
Ground bone	50	
Guar Gum	35	
Gumbase	42	
Guano	70	
Gypsum, crushed	90-100	
Gypsum, ground	75-80	
Hash, spice	66	
Hay, loose	5	
Hell blue dye	19	
Hemlock	25	
Hexanedioic Acid	45	
Hickory, dry	25	
Ice, crushed	35-45	up to 30
Ice, solid	57.4	
Insecticide	46	
Ional	47	
Iron, cast ductile	444	
Iron, cast gray	450	
Iron Ore	120-180	
Iron oxide	174	
Iron oxide, black	160	
Iron Sulfate	50-75	
Kaolin, clay	160	
Kaolin, talc	42-56	
Lactose	32	
Lamisay flour	34	
Latikra	34	
Lead, arsenal	72	
Lead, carbonate	240-260	
Lead, ore	180-230	
Lead, red	230	
Lead, white	250-260	
Lignite	42-55	30-45
Limanite	120	
Lime, bricks	41-83	
Lime, ground	60	
Lime, hydrated	40	30-45
Lime, pebble	53-56	
Lime, quick	54	
Limestone	100	
Limestone, agriculture	68	
Limestone, dust	55-95	
Limestone, filler	63	
Limestone, loose	100	
Limestone, pulverized	85-90	45 & up
Lindane	56	
Linseed, cake	48-50	
Linseed, whole	45-50	up to 30

Material	Bulk Density lb/cu. ft.	Angle of Repose
Magnesia	77	
Magnesium chloride	33	
Magnesium oxide	10-135	
Magnesium, sulfate	40-50	
Mahogany Spinach	53	
Maize	45	
Malt, flour	40	
Malt, meal	36-40	
Malt, powder	40	
Malt, wheat	41	
Manganese Ore	125-180	
Manganese Oxide	120	
Manganese Sulfate	70	
Manganese Solid	475	
Manure	25	
Marble, crushed	80-95	30-45
Maple	49	
Masonry	185	
Material 199	67	
Meat	50-55	
Mercury	849	
Metallic, flake	35	
Mica, ground	13-15	30-45
Mica, flakes	17-22	
Mica, solid	181	
Mica, soapstone	46	
Milk, malted	27-35	45 & up
Milk, powdered	36	45 & up
Mill Scale	100-125	
Milltown	35	
Mineral Oxide	35	
Molybdenum	107	
Mortar, wet	150	
Moulding compound	42	
Muriate of Potash	77	
Mustard, powdered	16	
Mustard, spice B	45	
Naphthalene Flakes	36	
Neutral Granules	24	
Nickel Ore	150	
Nicotinic Acid	35	
Oskite	60	
Oak, live, dry	59	
Oats	25-35	32
Oat flour	33	
Oil cake	48-50	
Oil, linseed	58.8	
Oleomargarine	59	
Orange Peel, dry	15	
Paper Pulp (15%)	62	
Paper Pulp (6 15%)	60-62	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Parazate	18	
Peanut Brittle	36	
Peanuts, unshelled	15-24	30-45
Peas	45-50	
Pentserythritol	43	
Peppermint	32	
Pharmaceutical Mix	39	
Pharmaceutical Lubricant	9	
Phenol Formaldehyde	30	
Phosphate	94	
Phosphate, crushed	75-85	26
Phosphate, granular	90-100	
Phosphate, soda	25-31	
Phosphoprotein	36	
Pie Crust Mix	34	
Pine, white, dry	26	
Pine, yellow south	45	
Pitch	72	
Plastic beads	46	
Plastics, chopped	37	
Plastics, lrg. flakes	19	
Plastics, small flakes	34	
Plastics material color	34	
Plastics, spheres	42	
Plastics, Powder B	25	
Plastics, Scrap	40	
Polyester, film	5	
Polyethylene	42	
Polyethylene, flakes	6	
Polyethylene, pellets	35	
Polyvinyl Chloride	40	
Pork Spice	72	
Potassium Bromide	114	
Potassium Chloride	73	30-45
Potassium Iodate	128	
Potassium Nitrate (1/2)	76	
Potassium Sulfate	42-48	
Potatoes, dried	58	
Pie Mix	34	
Protein Supplement	33	
PVC Powder	30	
Quartz	85	
Raisins	48	
Red Oxide	72	
Red Color Concentrates	32	
Redwood	26-30	
Resin	30-37	
Resin Luron	39	
Rice, chopped	64	
Rice, grits	42-45	up to 30
Rice, rough	32-36	30-45
Rip Rap	80-105	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Rolaids	64	
Rosin	67	
Rubber Composition	33	
Rubber Caoutchouc	59	
Rubber, mfg.	95	
Safflower	45	
Safflower, cake	50	
Sal Ammoniac	52	
Salicylic Acid	29	
Salt (1/8)	50	
Salt, coarse	45-55	30-45
Salt, dry coarse	45-50	
Salt, fine	70-80	
Sand, damp	110-130	45 & up
Sand, dry	90-110	
Sand, foundry (1/8)	90	
Sand, foundry (1/2)	90	
Sand, rammed	100-110	
Sandvoids full of H2O	110-130	15-30
Santonox	18-45	
Saran Powder	35	
Sawdust (wet)	24	
Scale	125-160	36
Sewage	40-50	
Shale, crushed	85-90	39
Shale, solid	162	
Shavings, wood	15	
Silene	15	
Silene & Zinc	15	
Silica Gel	42	
Silicon Carbide	15-88	
Silver Powder	69	
Sinter	90-110	
Slag Furnace (+1/2)	60-65	
Slate, crushed	80-90	28
Slate, solid	165-175	
Sludge	45-55	
Snow, packed	15-35	
Soap, flakes	5-20	30-45
Soap, powdered	20-25	30-45
Soapstone	40-50	
Soda Ash, heavy	55-65	30-45
Sodium Aluminate	72	
Sodium Bisulfate	90	
Sodium Chloride	84	
Sodium Nitrate	70-80	24
Sodium Phospho Aluminate	67	
Sodium Pysophosphate	63	
Sodium Sulfate, dry (1/8)	65-85	
Sodium Tripolyphosphate	58-64	
Sorghum, seed	32-52	
Soybeans, cake	40-43	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Soybeans, flakes, raw	20-26	
Soybeans, meal, cold	40	
Soybeans, meal, hot	40	
Spice (Vienna)	63	
Spruce	28	
Stabilizer	71	
Sta-nut	52	
Steatite	25-50	
Steel, solid	469.6	
Steel Turnings	60-120	45 & up
Sugar Beet, dry	12-15	
Sugar Beet, wet	25-45	
Sugar, powdered	50-60	
Sugarcane	15-18	45 & up
Sulphur, crushed	50-60	
Sulphur, dust	50-70	30-45
Sulphur, powdered	50-60	
Taconite	116-130	
Talc, granulated	50-65	
Talcum powder	55	
Tanbark	55	
Tar	69-75	
Tea	27	
Tin Cast	459	
Timothy, seed	36	
Titanium Sponge	60-70	

Material	Bulk Density lb/cu. ft.	Angle of Repose
Tobacco, scraps	15-25	45 & up
Tobacco, stems	16-25	45 & up
Traprock, compact	187	
Tricalcium Phosphate	40-50	
Trichlorocyanuric Acid	50	
Triple Super Phosphate	50-55	
Trisodium Phosphate	60	40
Tumeric	51	
Ulexite	75	
Vermiculite	62	
Vermiculite, ore	80	
Vicrum	35	
Vinyl Resin	36	
Vitamin Mix	43-49	
Walnuts	35-40	
Wax	26	
Wheat, cracked	46	30-46
Wheat, cut	45-48	
Wheat germ	35-40	
White Powder	28-45	
Wood, bark	10-20	
Wood, chips	10-30	45 & up
Yellow Corn Flour	33	
Zinc Concentrate	75-80	
Zinc Hydrosulphate	44	
Zinc Oxide, heavy	10-15	45 & up

Load Cell Bolt Torque Values

Cap screw diameter	Recommended Torque (ft lb)			
	Heat-treated 1038 hex head SAE grade 5		Alloy hex head SAE grade 8	
	UNC	UNF	UNC	UNF
1/4"	11	13	12	15
5/16"	21	23	25	30
3/8"	38	40	50	60
7/16"	55	60	85	95
1/2"	85	95	125	140
9/16"	125	140	175	195
5/8"	175	210	245	270
3/4"	300	330	425	460
7/8"	450	490	660	700
1"	680	715	990	1050
1-1/8"	885	990	1470	1655
1-1/4"	1255	1380	2100	2310
1-3/8"	1635	1875	2750	3110
1-1/2"	2180	2430	3640	4100

Notes:

1) Based on dry assembly. Variables such as lubrication, plating, etc. may reduce the values listed above as much as 20%, and must be taken into consideration.
2) General formula for calculating Torque is as follows: Torque in Inch lb=0.2 x Nominal Diameter of Screw x Load in lb, where load = 80% of yield strength, expressed in lb, not pounds per square inch.
3) The tension induced in a cap screw may be checked by measuring overall length before torquing and then under torque load. The screw stretches .001" per inch of screw length for each 30,000# PSI induced tension. Applies only to loads below the yield point.

Wind and Seismic Effects on Vessel Stability

Other than forces resulting from the impact of a vehicle, wind and seismic forces are the most important external forces which might affect a weigh vessel. The threat from vehicular traffic can be guarded against using properly-designed guard rails. The effects of wind and seismic forces, where they are a factor, must be accounted for in the design of a weigh vessel. At a minimum, consideration of these forces might affect the capacity of load cells selected. In more extreme cases they may dictate the use of additional restraints on a vessel. In general, weigh modules have a lift-off capacity of 150% of capacity, and a side-load capacity of 100% of capacity.

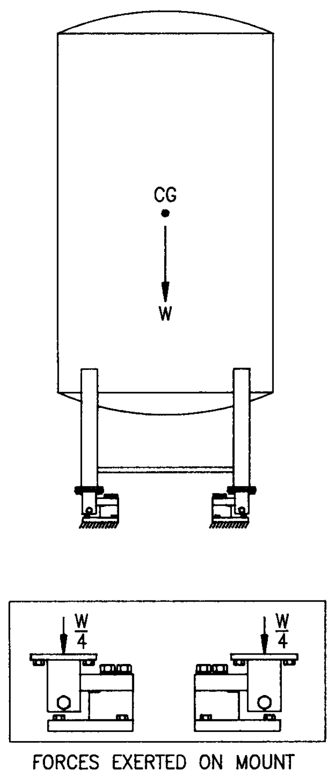


Figure 1-26

In general, these forces act horizontally at the center of gravity (CG) of the weigh vessel. Figure 1-26 illustrates a four-legged vertical cylindrical vessel and the forces acting on it in the absence of wind or seismic forces. W is the vessel's weight (an empty and full vessel should be considered separately, as either one may be the limiting case), and it acts through the vessel's center of gravity. Assuming that the four legs are arranged symmetrically, then each leg will exert a force of 1/4W on each mount.

Figure 1-27 illustrates the same vessel with the addition of a horizontal force F (the result of wind or seismic activity.) The vessel exerts a horizontal force of 1/4 F on each load cell mount. Also, there is an additional force of F_{0T} acting on the left-hand side load cell mounts, which means that each is now carrying a load of 1/4W + F_{0T}. On the right-hand side load cell mounts, a force of F_{0T} is also induced as a result of F, however, this force is in the opposite direction to the existing 1/4W and the total force here is reduced to 1/4W - F_{0T}. Hence, you will see that load is being transferred from the mounts on one side of the vessel to those on the other. The load cell capacity selected must be capable of withstanding this additional force for the extremes of wind or seismic forces expected. If F was increased to where F_{0T} equalled W/4 then there would be zero load on the right hand mounts and the load would have doubled to W/2 on the left-hand mounts. Further increase in F will cause the vessel to lift up on the right-hand mounts and may, in the extreme case, cause the vessel to tip.

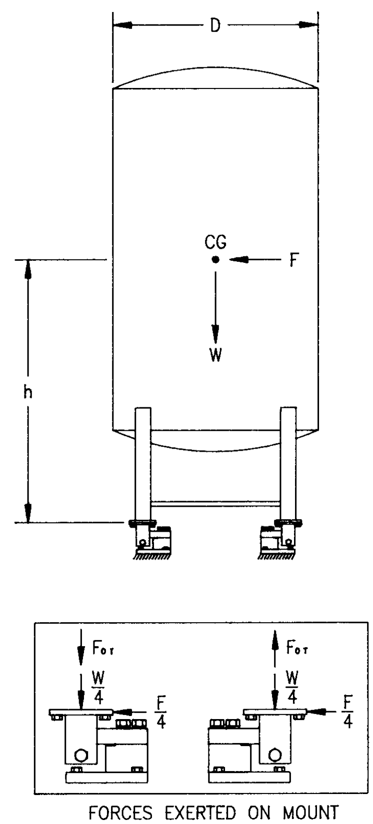


Figure 1-27

The relationship between F_{0T} and F may be stated as follows for the vessel shown in Figure 1-27:

$$F_{0T} = .7Fh/D$$

where h = height to the center of gravity and D = vessel diameter.

It is desirable to reduce F_{0T}; this can be done as might be expected by reducing F or h or by increasing D. Dimension h can be reduced by reducing the vessel height (not always practical) or by placing the mounts at the vessel's center of gravity as illustrated earlier. In this case h = 0 and hence F_{0T} = 0.

It is interesting to compare the stability of a vessel supported on 3 and 4 load cell mounts. Figure 1-28 shows a top view of a vertical cylindrical vessel supported at 3 and 4 points (broken and solid lines respectively). The vessel will tend to tip about a straight line drawn between adjacent support points; the greater the distance from the center of gravity to this line the more stable the vessel will be. A vessel supported at 3 points will be approximately 29% less stable than if it were supported at 4 points.

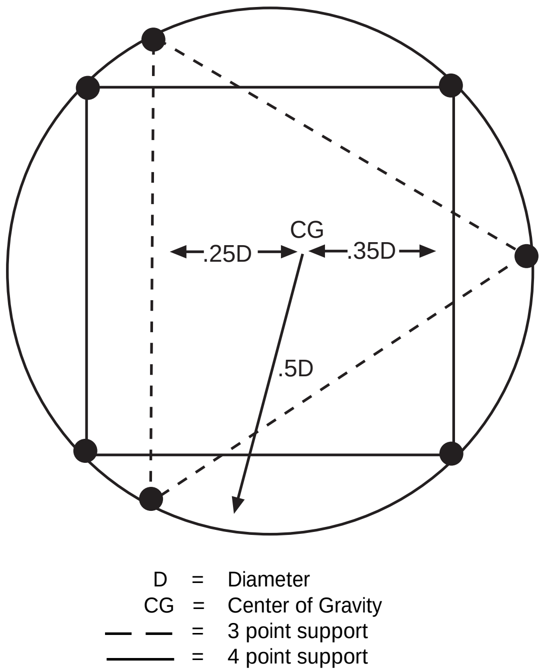


Figure 1-28: Top view of cylindrical vessel

Because of the many variables in vessel design and site conditions, it is impossible to deal comprehensively with the calculation of wind and seismic forces in this text. However, the following subsections deal with these forces in general terms and point out the information necessary for a complete analysis. Refer to the Uniform Building Code (UBC) for further details.

While the effects of both wind and seismic forces should be considered, it is acceptable to consider these forces in isolation.

Wind Forces

Consideration must be given to the effects of wind loading when a weigh vessel is installed outdoors. This is particularly important for tall slender vessels, vessels installed in exposed locations (for example, facing a large body of water), or those installed in a high wind-speed location. In analyzing the effects of wind loading, it must be assumed that the wind may blow at a vessel in any horizontal direction.

Figure 1-29 illustrates the effect of wind blowing at a vertical cylindrical vessel. Note that not only is there a force exerted against the windward side of the vessel, but there is also a suction force on the leeward side. These forces are additive, and tend to tip the vessel in the direction of the wind. At right angles to the wind direction are suction forces pulling on each side due to the increased speed of the wind at these points. Since these are equal and opposite in direction, they have no net effect on the stability of the vessel.

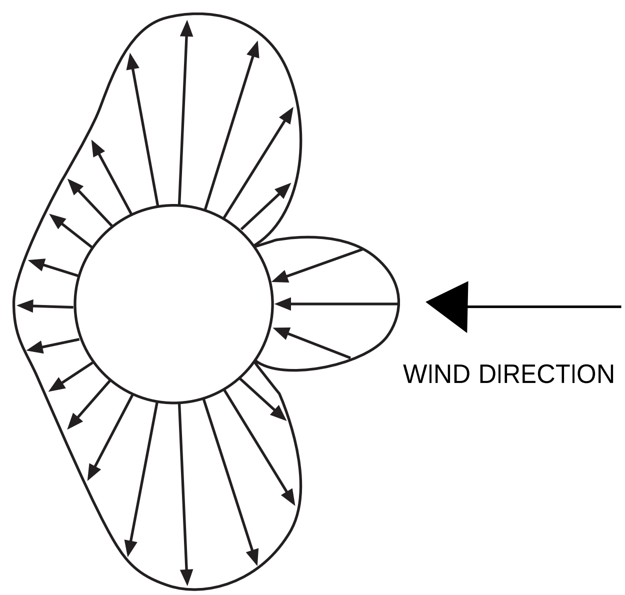


Figure 1-29

To perform a complete wind force analysis, the following information is necessary:

■ Vessel: The vessel's dead and live weights, number of supports, and overall dimensions such as height, length of legs, diameter, etc.

■ Minimum basic wind speed: This may be taken from Figure 1-30, which is a map of the USA superimposed with wind speed contours. This map is based on a 50-year mean recurrence interval which has traditionally been accepted as a reasonable risk. If local records indicate higher 50-year wind speeds, then the higher values should be used. This map does not consider the effects of tornadoes.

■ Exposure: The exposure conditions at the site must be known. Built up or rough terrain can cause a substantial reduction in wind speed. The United Building Code (UBC) defines 3 exposure categories:

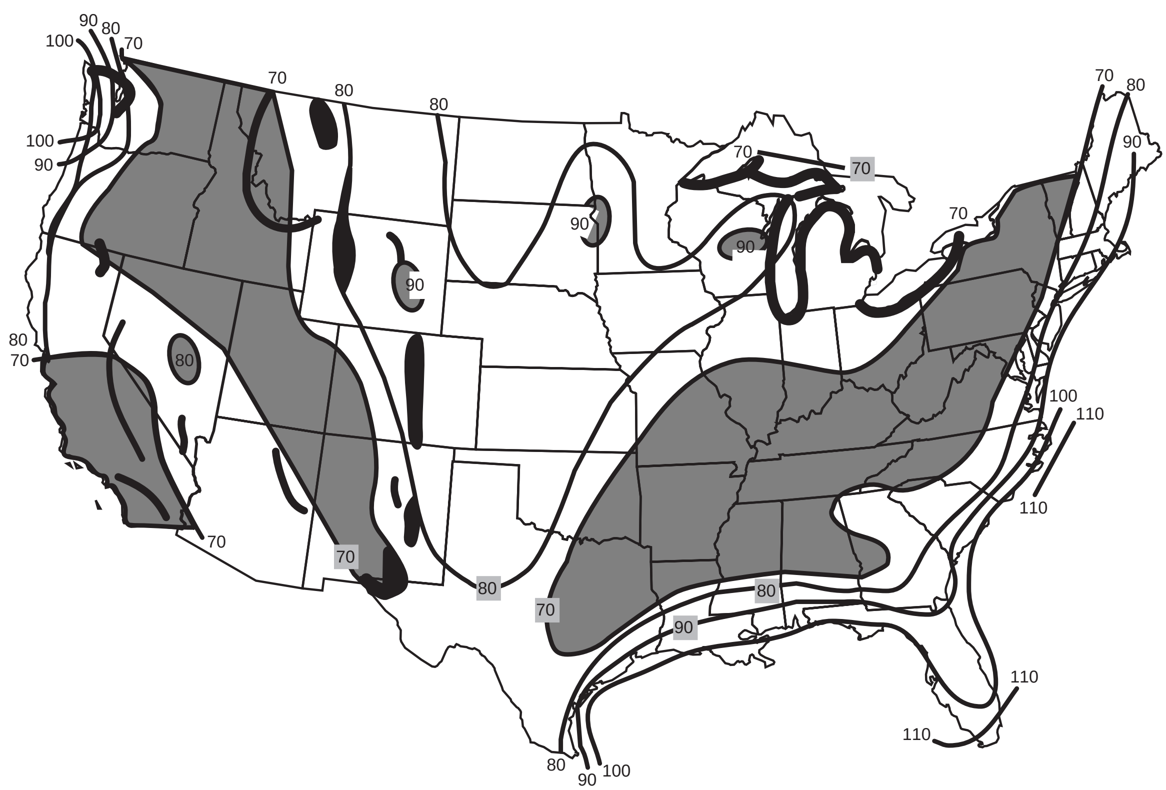
Exposure B: has terrain with buildings, forest or surface irregularities 20 feet or more in height covering at least 20% of the area extending one mile or more from the site.

Exposure C: has terrain which is flat and generally open, extending one half mile or more from the site in any full quadrant.

Exposure D: represents the most severe exposure in areas with basic wind speeds of 80 mph or greater and has terrain which is flat and unobstructed facing large bodies of water over one mile or more in width relative to any quadrant of the vessel site. Exposure D extends inland from the shoreline 1/4 mile or 10 times the vessel height, whichever is greater.

■ Importance Factor: An importance factor of 1.15 is used for essential facilities which must be safe and usable for emergency purposes after a windstorm in order to preserve the health and safety of the general public. Such facilities include medical facilities having surgery or emergency treatment areas, fire and police stations. A factor of 1.0 is used for all other facilities.

With this information, the wind forces can be calculated in accordance with methods described in the UBC. This information may be used to verify the stability of the vessel using standard mounts, or to design additional restraints if deemed necessary.



NOTES: Basic wind speed 70 mph Special wind region

1. Values are fastest mile speeds at 33 feet above ground for Exposure Category C and are associated with an annual probability of 0.02.
2. Linear interpolation between wind speed contours is acceptable.
3. Caution in use of wind speed contours in mountainous regions of Alaska is advised.
4. Wind speed for Hawaii is 80 and Puerto Rico is 95.
5. Wind speed for Alaska varies from 70 inland to over 110 in coastal areas.
6. Where local records or terrain indicate higher 50-year wind speeds, they shall be used.
7. Wind speed may be assumed to be constant between the coastline and the nearest inland contour.

Figure 1-30

Seismic Forces

Figure 1-31 is a seismic zone map of the United States. The various zones are numbered 0 (little likelihood of damage) through 4 (likelihood of major damage) which indicate, on an ascending scale, the severity of damage likely as the result of earthquakes. The effects of seismic forces should be considered on vessels being installed in zones 1 through 4.

The following information is required in order to perform a complete seismic analysis.

- Vessel: The vessel's dead and live weights, number of supports, and overall dimensions such as height, length of legs, diameter, etc.
- The seismic zone (from Figure 1-31) in which the vessel will be installed.
- Is the vessel freestanding, mounted on a structure, or on the roof of a building?
- Function of Structure. Does the vessel :
  1. Contain material or equipment necessary for the protection of essential facilities (hospitals, fire and police stations), hazardous facilities or special occupancy structures (schools, jails and public utilities)?
  2. Contain sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released?
  3. Support the operation of public utility facilities?
  4. Perform a function not listed above.
- Site geology/soil characteristics and the vessel's structural period, if available.

With this information, the forces resulting from seismic activity can be calculated according to methods described in the Uniform Building Code (UBC).

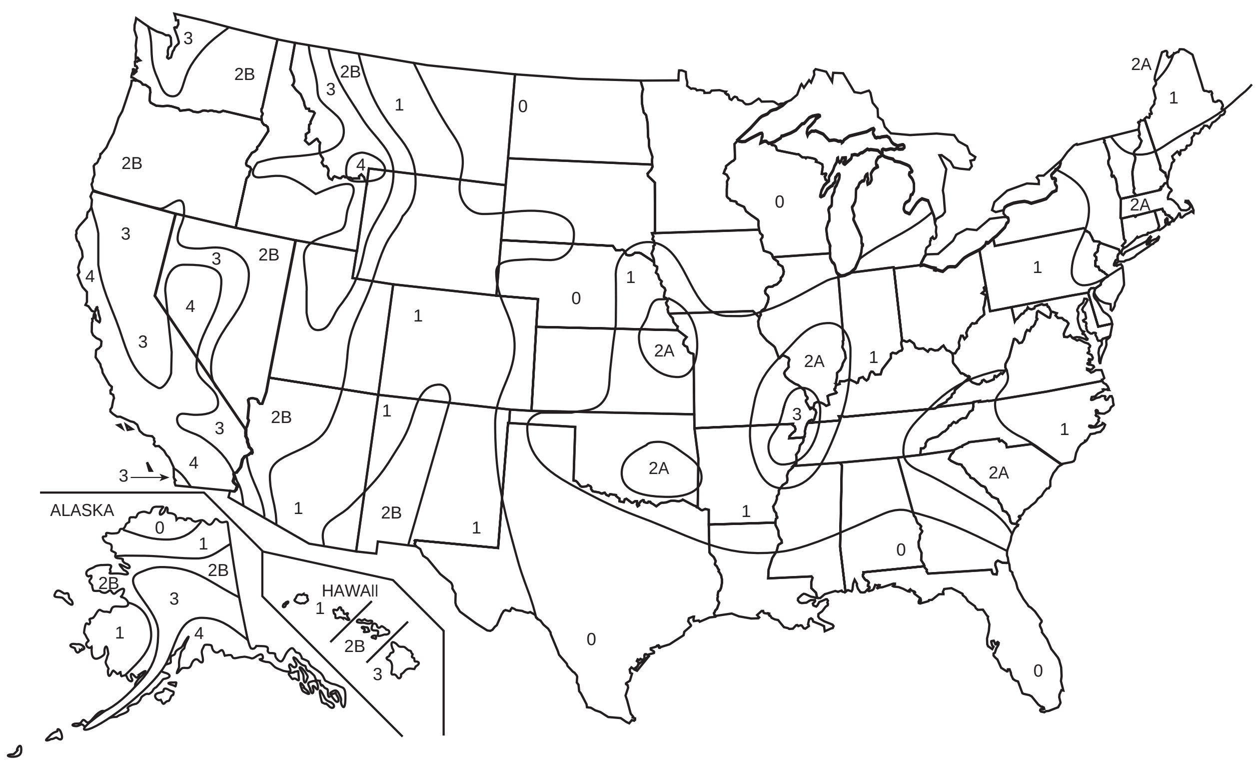


Figure 1-31

WEIGH MODULES

Single-End Beam Load Cell Modules

Introduction

Single-end beam load cells offer many advantages when used in well-designed weigh modules. The modules using single-end beam load cells have a low profile, and are generally self-checking. Load cell replacement is possible in most single-ended beam mount systems by raising the vessel only enough to remove pressure from the cell.

General Mounting Principles

- The mounting surface should be flat and level.
- The mounting block should be thick enough to provide adequate threads for the mounting screws.
- The corner of the mounting surface (where the cell cantilevers out) must be hard to prevent peening.
- The mounting bolts should be at least grade five to prevent stretching or the possibility of breaking.
- The load should be applied vertically through the center line of the load hole (the load may be applied from above, as illustrated in Figure 2-1, or may be hung from below).
- The load introduction means must provide flexibility to avoid the transmission of extraneous forces and to tolerate the unavoidable deflection of the load cell itself.
- The mounting bolts should be torqued to specified values.

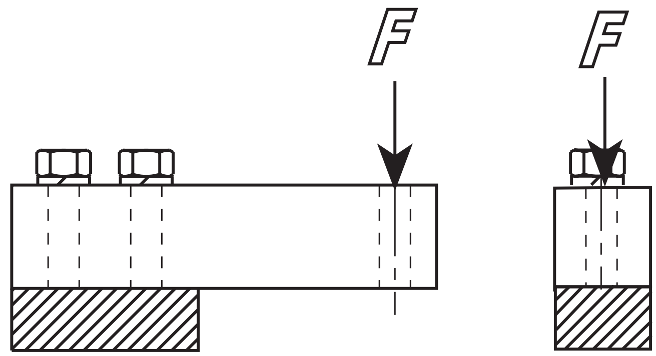


Figure 2-1

Single-End Beam Orientation

Figure 2-2 illustrates four different vessels and recommended mounting configurations for single-end beam weigh modules. See the subsection on Paramounts® for special movement considerations that apply to this unique single-ended beam system.

The vessels in the upper row, at right, illustrate a vertical cylindrical vessel. Note that the longitudinal axis through each load cell points towards the center of the vessel.

This principle could also be used for the vessels in the lower row, if it were convenient to mount the cells in each corner with the longitudinal axis pointing toward the center. However, it may be more convenient, and is acceptable, to mount the cells as illustrated. As these cells are relatively immune to extraneous forces applied along the longitudinal axis of the cell, it should point in the direction of any prevalent side force (for example, on a roller conveyor, the load cells should point in the direction of travel).

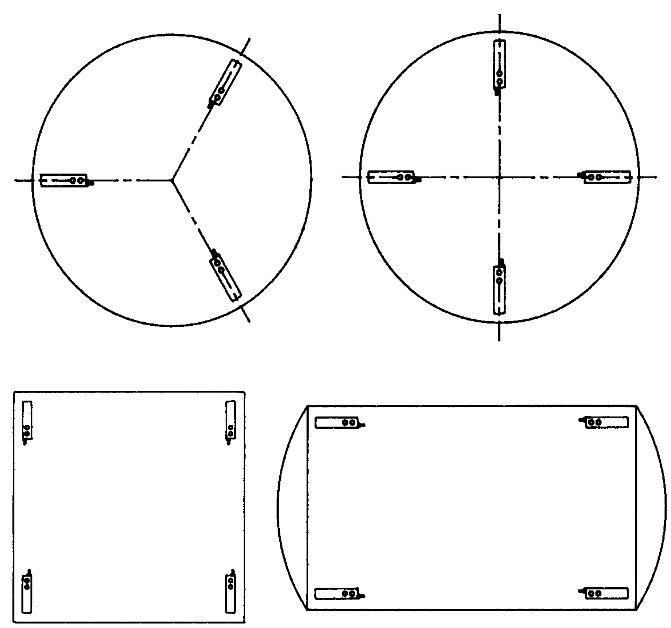


Figure 2-2

Rice Lake Weighing Systems Weigh Modules

SURVIVOR® 1700HE Modules

These light- to medium-capacity modules use single-ended beam load cells in capacities from 5 kg-250 kg (11-550 lb) and 500-5,000 kg (1,100-11,000 lb). The SURVIVOR 1700HE is ideally suited for light- to medium-capacity micro-ingredient batching and mixing in a variety of hostile environments, especially where moisture is present. This module provides superior corrosion, moisture ingress, and mechanical protection. The load cells are waterproof guaranteed and OIML C3 certified (20 kg-5,000 kg) to offer the ultimate in durability and accuracy.

Allowable Movement

Figure 2-3 illustrates the 1700HE module's capability to handle movement. The load may be checked in one of two directions. This allows positioning in one of two orientations for proper checking.

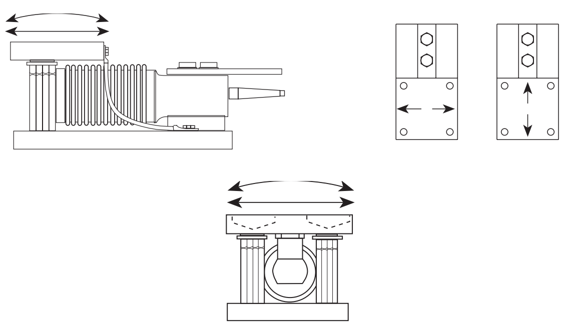


Figure 2-3: SURVIVOR 1700HE

Construction and Features

1) IP66/68 environmental rating is guaranteed against moisture damage.
2) Load introduction mechanism isolates load from overloads, underloads and extreme side loads, minimizing mechanical failure.
3) Weldless construction improves pressure washdown performance.
4) Integral jacking/shipping bolts offer a means to remove the load from the load cell for quick removal and replacement of load cell and worry-free transport.
5) All modules come standard in stainless steel.

Typical Application

Typical applications for the Survivor 1700HE include light-capacity micro-ingredient batching and mixing.

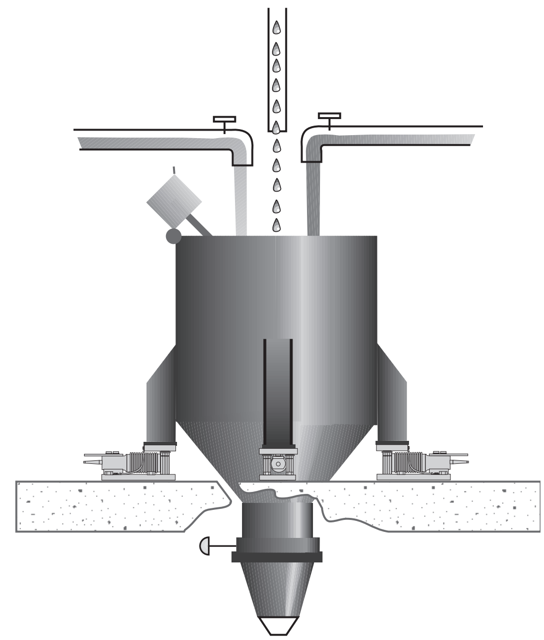


Figure 2-4: SURVIVOR 1700HE in micro-ingredient batching

RL50210 TA Modules

These low-capacity modules use single-ended beam load cells in capacities from 50 lb to 2,500 lb. The resiliency of a neoprene-cushioned mounting pad attached directly to the cell and vessel accommodate limited movement and minor misalignment. These units are ideal for small tanks, platforms, and in-motion conveyor applications where checking requirements are low. The direct connection of the vessel to the flexible neoprene pad acts to cushion shock loads.

Allowable Movement

Figure 2-5 illustrates the RL50210 TA module's capability to handle movement. The arrows indicate the various means by which the load introduction plate can move relative to the cell to minimize the transfer of extraneous forces.

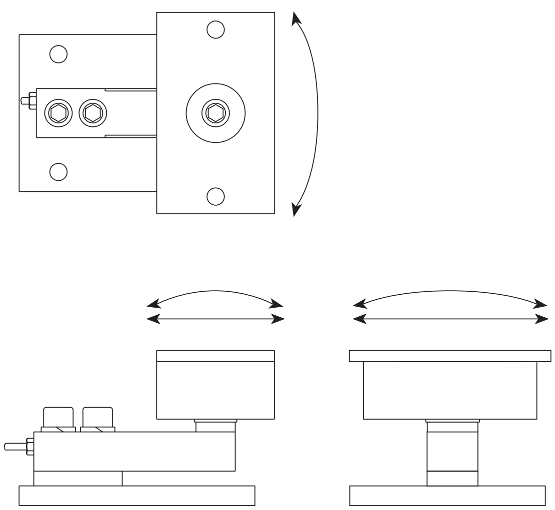


Figure 2-5: RL50210 TA

Construction and Features

1) The module has a large base plate and spacer washer, and the load cell is screwed directly to the base plate.
2) Load introduction is through a steel plate bonded to a neoprene pad which accommodates vessel movement in all directions.
3) Because the module can compress vertically, it provides a degree of protection against shock loading.
4) Because of the neoprene pad, this module provides little lift-off protection or lateral restraint. Also, because the neoprene pad compresses as load is applied, this module should not be used where the vessel has attached piping or stay rods. Loosely fitting safety check rods may be used if required.
5) This module is available in capacities from 50 lb to 2,500 lb in mild steel, and 500 lb to 2,500 lb in 304 stainless steel.
6) Capacities 500 lb to 2,500 lb incorporate an overload stop under the free end of the cell.
7) Capacities 50 lb to 250 lb accommodate an RL50210 load cell while capacities 500 lb to 2,500 lb accommodate an RL30000 load cell.

Typical Application

These modules should be attached so their longitudinal axis aligns with the direction of greatest expected movement of the vessel or conveyor. On a roller conveyor, this would normally be along the line of conveyor travel.

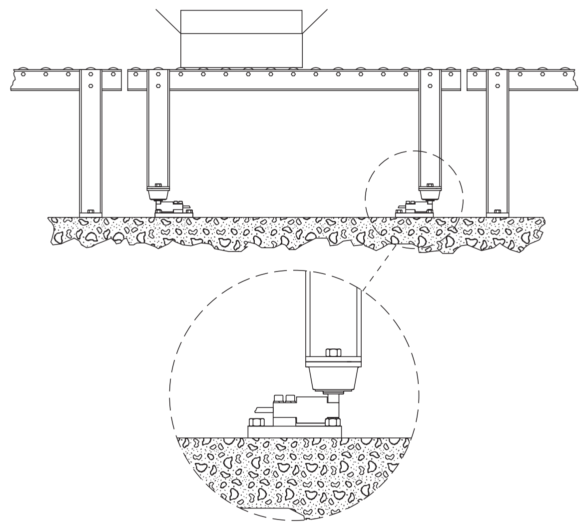


Figure 2-6: RL50210 TA on conveyor

RL1800 Modules

These modules use single-end beam load cells in center-pivoted modules with capacities up to 10,000 lb per module. While these are compression-style modules, the cell is actually mounted in tension since the load is introduced through a center loading bolt in a hanging trunnion suspended beneath the load cell. The trunnion can pivot in all directions on a set of spherical washers, allowing the top plate (attached to the vessel) to rock without twisting the load cell. This arrangement makes the modules self-centering, and able to accommodate movement in all directions. This module is self-checking and provides lift-off protection.

The RL1800 modules allow the installer to adjust overall height easily with the center loading bolt that is attached to the hanging trunnion. This adjustment feature speeds the process of equalizing the load between all modules. These modules allow load cell removal and replacement without raising the tank—an important consideration in some installations.

Allowable Movement

Figure 2-7 illustrates the RL1800 module with arrows indicating allowable movement.

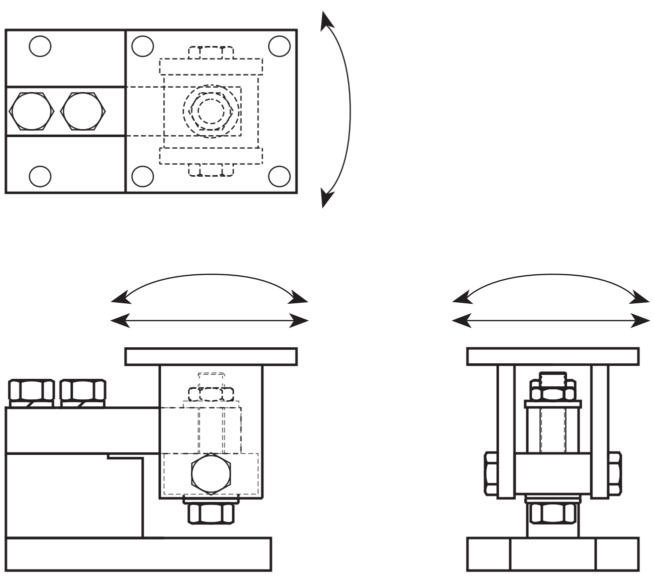


Figure 2-7: RL1800

Construction and Features

1) A base plate and spacer support the load cell.
2) A trunnion block is suspended below the free end of the cell and is attached to the cell using a bolt in tension which is screwed into a threaded load hole. A spherical washer set is placed between the bolt head and block.
3) A chair arrangement is attached to the trunnion block through pivot screws, and the load is applied to the top plate of this chair. This arrangement allows the chair to move in the directions indicated in Figure 2-7.
4) Because the load is suspended from the underside of the cell, the module is self-centering; that is, after a disturbance temporarily moves the top plate laterally, it will tend to return to its original position under the influence of gravity.
5) The module provides lift-off protection and lateral restraint.
6) The module provides height adjustment.
7) This module can accommodate a broad range of alloy steel, stainless steel and hermetically-sealed stainless steel load cells.
8) The RL1800 module is available in capacities from 250 lb to 10,000 lb in both mild steel and 304 stainless steel.

Typical Installation

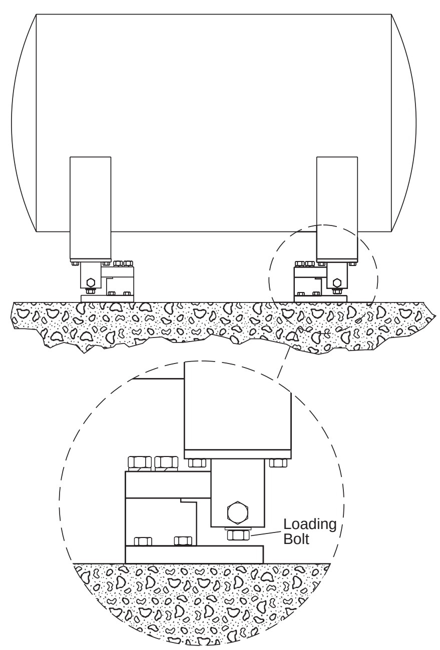


Figure 2-8: RL1800 modules on horizontal cylindrical tank

SURVIVOR® 1855HE Modules

These modules use single-ended beam load cells in center-pivoted modules with capacities up to 10,000 lb per module. Load cells are NTEP-certified, 1:5000 divisions Class III load cells for up to 0.02% total error. While these are compression-style modules, the cell is actually mounted in tension since the load is introduced through a center loading bolt in a hanging trunnion suspended beneath the load cell. The trunnion can pivot in all directions on a set of spherical washers, allowing the top plate (attached to the vessel) to rock without twisting the load cell. This arrangement makes the modules self-centering, and able to accommodate movement in all directions. This module is self-checking and provides lift-off protection.

The 1855HE modules allow the installer to adjust overall height easily with the center loading bolt that is attached to the hanging trunnion. This adjustment feature speeds the process of equalizing the load between all modules. These modules allow load cell removal and replacement without raising the tank—an important consideration in some installations.

Allowable Movement

Figure 2-9 illustrates the 1855HE module with arrows indicating allowable movement.

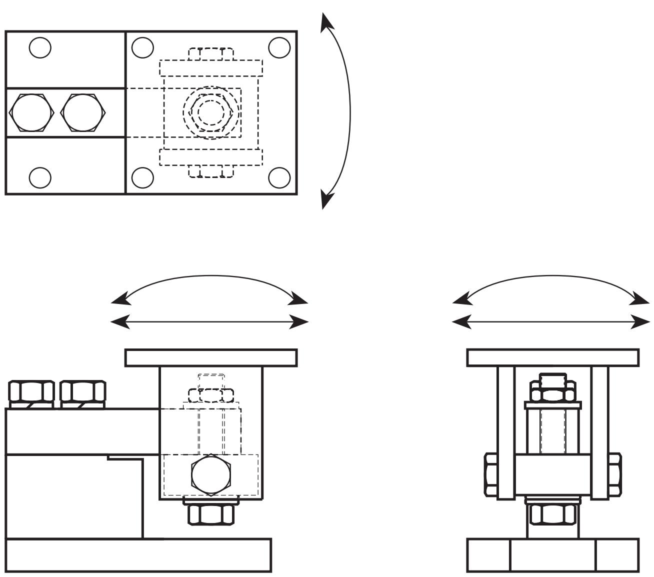


Figure 2-9: SURVIVOR 1855HE

Construction and Features

1) A base plate and spacer support the load cell.
2) A trunnion block is suspended below the free end of the cell and is attached to the cell using a bolt in tension which is screwed into a threaded load hole. A spherical washer set is placed between the bolt head and block.
3) A chair arrangement is attached to the trunnion block through pivot screws, and the load is applied to the top plate of this chair. This arrangement allows the chair to move in the directions indicated in Figure 2-9.
4) Because the load is suspended from the underside of the cell, the module is self-centering; that is, after a disturbance temporarily moves the top plate laterally, it will tend to return to its original position under the influence of gravity.
5) The module provides lift-off protection and lateral restraint.
6) The module provides height adjustment.
7) Hermetically-sealed stainless steel load cells are guaranteed against moisture damage.
8) The 1855HE module is available in capacities from 1000 lb-10,000 lb in stainless steel
9) A Teflon®-jacketed cable and integral conduit adapter heighten chemical and moisture resistance.

Typical Installation

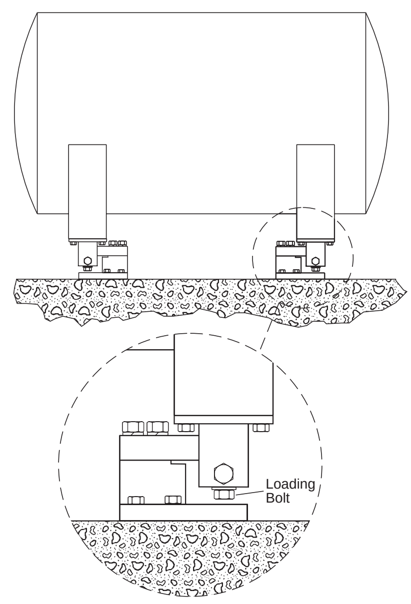


Figure 2-10: SURVIVOR RL1800 Modules on Horizontal Cylindrical Tank

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RL1900 Modules

The RL1900 module is similar in design to the RL1800, but accommodates slightly more lateral movement than the RL1800.

Allowable Movement

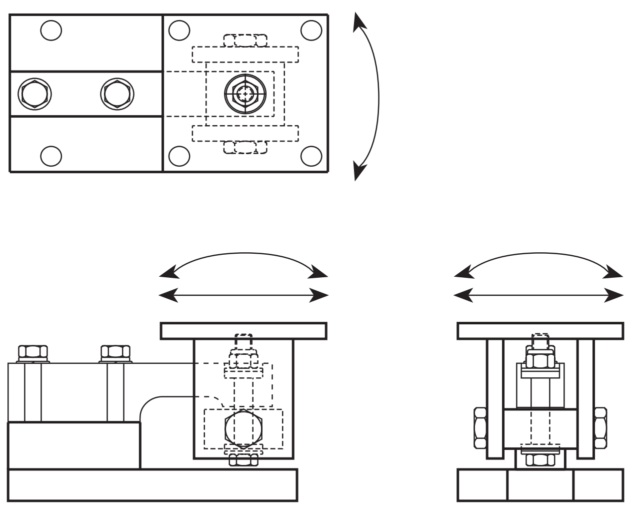

Figure 2-11: RL1900 Module

Construction and Features

1) A base plate and spacer support the load cell.
2) A trunnion block is suspended below the free end of the load cell. It is attached to the load cell using a bolt which passes through the clearance load hole and is retained by a nut at the top of the cell. Two spherical washer sets are used; one sits between the bolt head and trunnion block, the other sits between the nut and the top of the load cell (which is counterbored to accept the washer set).
3) A chair arrangement is attached to the trunnion block through pivot screws; the load is applied to the top plate of this chair. This arrangement allows the chair to move in the directions indicated in Figure 2-11.
4) This module allows greater lateral movement than the RL1800 by virtue of the fact that the suspension bolt passes through a clearance load hole in the cell and has spherical washer sets at the top and bottom.
5) Because the load is suspended from the underside of the cell, the module is self-centering; that is, after a disturbance temporarily moves the top plate laterally, it will tend to return to its original position under the influence of gravity.
6) The module provides lift-off protection and lateral restraint.
7) The module provides height adjustment.
8) The RL1900 module is available in capacities from 1,000 lb to 10,000 lb in 304 stainless steel.
9) This module can accommodate both environmentally-protected and hermetically-sealed load cells—the HBM SB3 and the RTI SSB, respectively.

Typical Installation

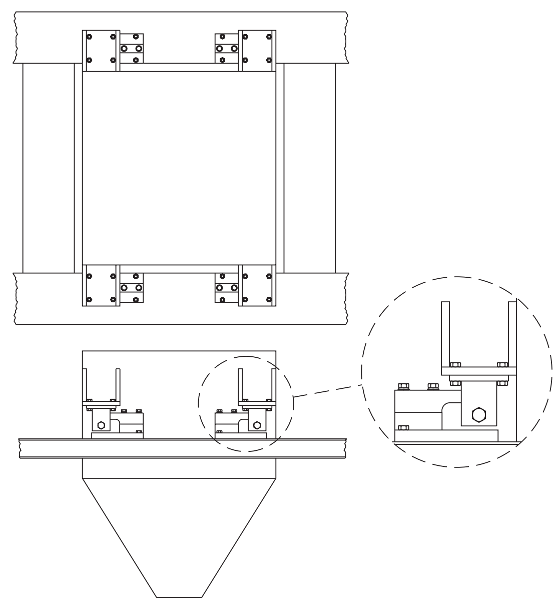

Figure 2-12: RL1900 modules on hopper scale

Paramounts® HS & Paramounts® EP

The versatile Paramounts vessel weighing system consists of three different modules, which together make a complete system of fixed and sliding modules with single-ended SB4 or SB5 load cells. This unique system allows a vessel to expand freely on sliding modules, yet the system is self-checking. All models are available in capacities to 22,500 lb.

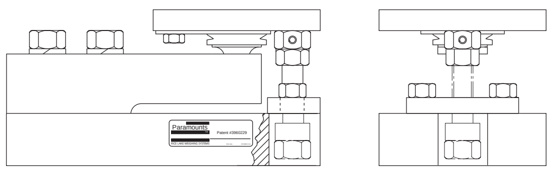

Figure 2-13

Allowable Movement

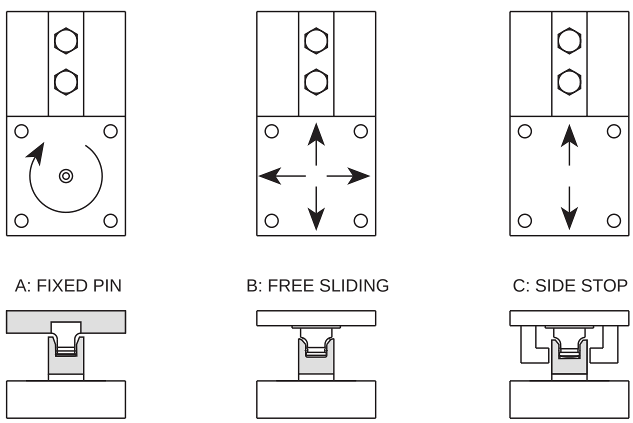

Figure 2-14

a) **Fixed Pin Module** - With the fixed pin module, the load is transferred from the top plate to the load cell via a load pin which enters a counterbore in the top plate and load cell. The pin acts as a pivot point and only allows the top plate to rotate while fixing that corner of the vessel.

b) **Free Sliding Module** - With the free sliding module, the load pin has a flat top surface on which the top plate is free to slide in all directions. To minimize friction, the top surface of the pin is Teflon®-coated and slides on a smooth stainless steel slider plate. The cleanliness of these two surfaces is assured by a neoprene suction seal.

c) **Side Stop Module** - The side stop module uses the same Teflon®-coated pin and stainless steel slider plate, but in addition it has side bumpers. These bumpers check the top plate movement laterally. The top plate is checked to move only in the direction of the longitudinal axis of the load cell.

A three-cell system uses one of each style of module; all additional modules are free-sliding.

Construction and Features

1) **No Torsional Effects:** All SB4 load cells incorporate a blind hole for load introduction. The load is introduced via a convex loading pin as seen in Figure 2-15. The convex surface allows the module's top plate to rock without twisting the cell. The load pin is centered in the load hole by a pliable polymer "O" ring. The bottom of the blind hole is located on the neutral axis of the SB4's sensing section. Therefore, torsional effects are virtually eliminated.

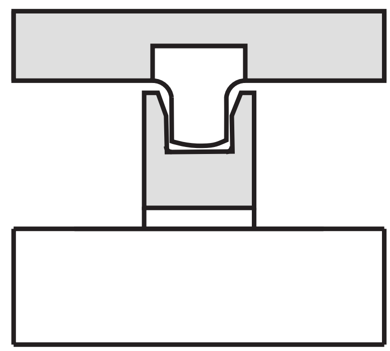

Figure 2-15

2) **Jacking Screw and Lift-Off Protection:** Each module consists of a base plate to which the load cell is screwed and a top plate through which the load is introduced; see Figure 2-14. A safety check screw is rigidly fixed to the top plate and passes through a large clearance hole in the washer plate attached to the base plate. This screw prevents lift-off and also may be used to jack up the empty vessel for load cell replacement.

3) **Allows Movement:** There are three different styles of modules resulting from differences in the top plate and loading pin design. Each serves as part of a complete system that allows free movement of the attached vessel.

4) **Matched Outputs:** The SB4 and SB5 load cells are matched output, stainless steel load cells. All Paramounts load cell kits use SB4 or SB5 load cells with outputs matched to ±.07%. This eliminates the need for corner trimming at initial installation or recalibration when a load cell is replaced.

5) **Withstands Hostile Environments:** Paramounts HS are available in mild steel or stainless steel with hermetically-sealed stainless steel load cells. Paramounts EP models come standard with stainless steel, environmentally-protected load cells.

6) Available in capacities to 22,250 lb in either mild steel or stainless steel.

Typical Applications

A three-module system would use one of each module. Scales requiring more than three modules use additional free sliding modules. Figure 2-16 is a typical example of a six-module system. The fixed pin module fixes the vessel in the corner, allowing it to rotate about the loading pin only. The vessel will expand outward from this corner. The side stop module placed at the opposite end keeps the vessel in check but does not restrict the expansion. The use of four free-sliding modules ensure that the vessel's expansion/ contraction is unrestricted in either direction.

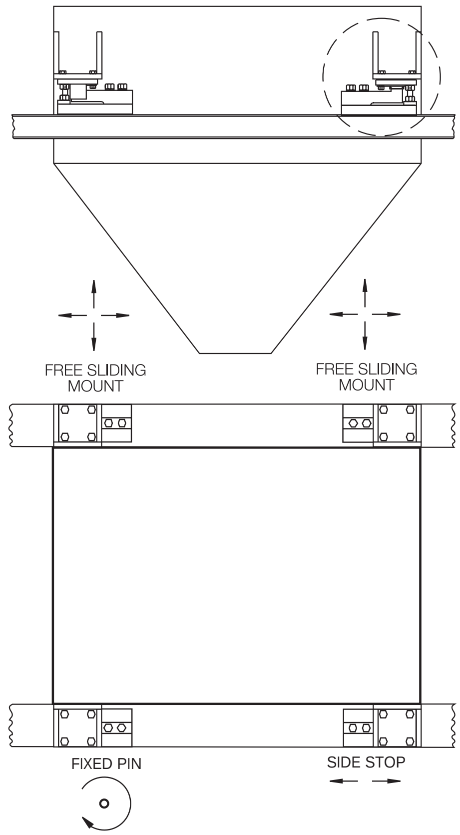

Figure 2-17: Paramounts on suspended hopper

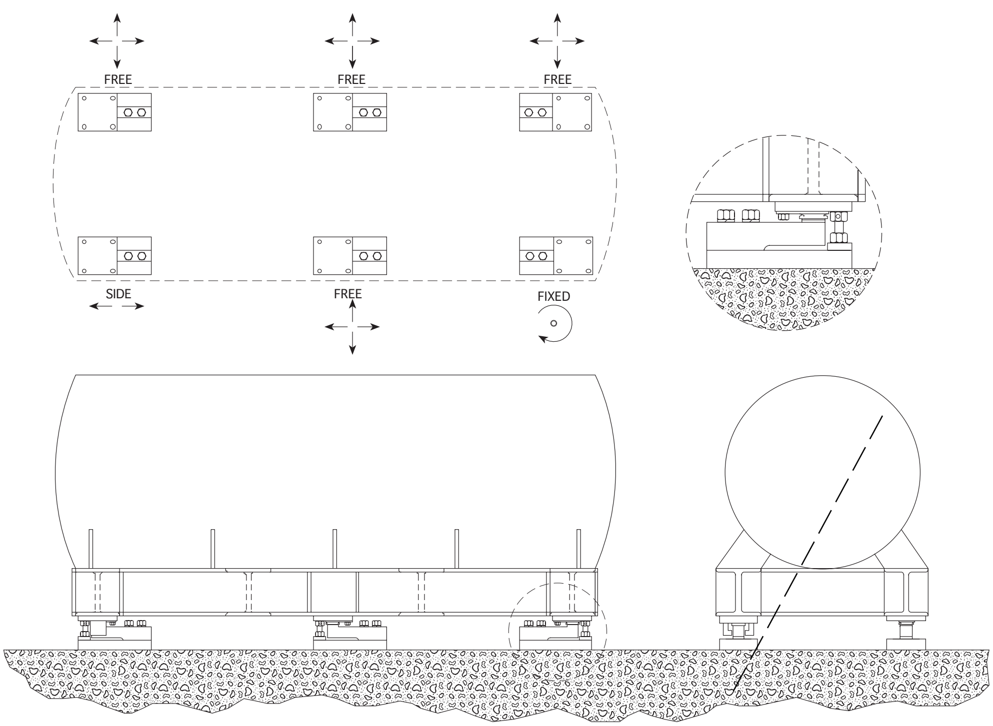

Figure 2-16: Paramounts mounting system on cylindrical tank

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Double-End Beam Load Cell Modules

Introduction

Double-end shear beams are medium- and high-capacity workhorses that are rugged, stable, and able to handle side loads well. The modules come in two varieties—end-supported cells loaded in the center, and center-supported cells loaded at the ends. The end-loaded cell is used in the Translink hanging-link truck scale module described later in this section. The more common center-loaded version described below is used in the RL1600, EZ Mount 1, and TSA mounting systems.

Figure 2-18 shows some important guidelines for applying load to a center-loaded, double-ended shear beam and for orienting a module using this type of load cell.

General Mounting Principles

- The load cell should be horizontal in both directions.
- The load should be applied vertically through the cell's center.
- The load should be introduced without producing a twisting effect around the center.
- The load must not move along the cell.

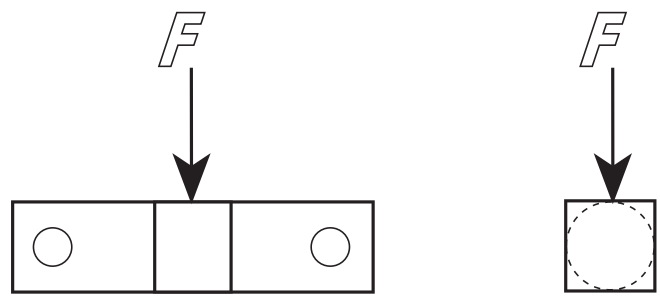


Figure 2-18

Double-End Beam Orientation

In Figure 2-19, we illustrate some recommended mounting methods for double-ended shear beams used in the RL1600 and EZ Mount 1.

The mounts for these cells allow the least restricted vessel movement in a direction perpendicular to the longitudinal axis through the cell.

The best mounting position for several vessel shapes is shown at right, where a line from the center of the vessel is at right angles to the longitudinal axis through the load cell. These recommendations are particularly important when significant thermal expansion/contraction is expected.

The TSA module should be oriented with the load cell's longitudinal axis in line with the expected movement. On a truck scale, that will normally be in the direction of truck travel. See Figure 2-25.

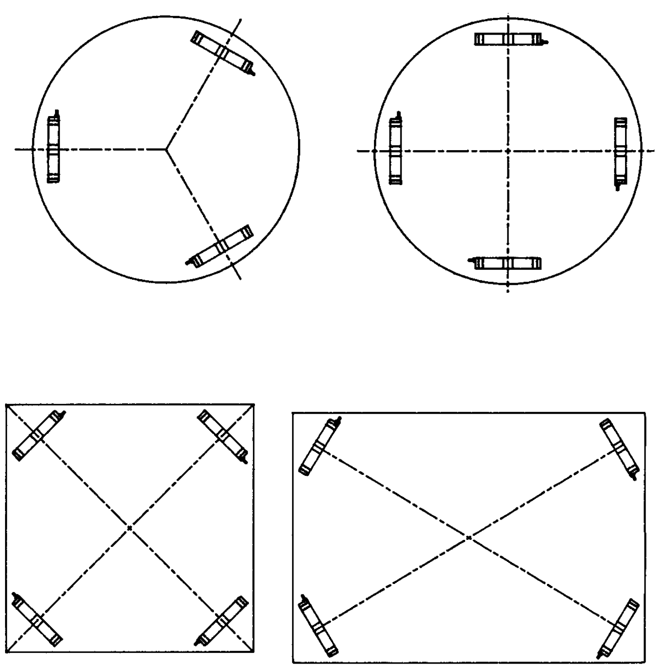


Figure 2-19

Rice Lake Weighing Systems Weigh Modules

RL1600 Modules

These assemblies are suitable for medium- to heavy-capacity applications because of the inherent strength and stability of the double-end center-loaded cell, supported at both ends on pins. The modules are self-checking in all directions while allowing some freedom for the vessel to expand/contract in a single direction by sliding on the mounting pins. The modules also offer lift-off protection to prevent the tank from accidental tipping.

The RL1600 module is a rugged and economical module for use where minimal expansion/contraction movement is expected. Precise alignment is critical with these modules, as there is little room for misalignment with the clamping yoke that holds the load plate to the load cell. Load cell replacement requires raising the vessel nearly an inch to remove the cell.

The 1600 series modules are available in either fabricated mild steel or cast iron, and in fabricated stainless steel where extra corrosion protection is required.

Allowable Movement

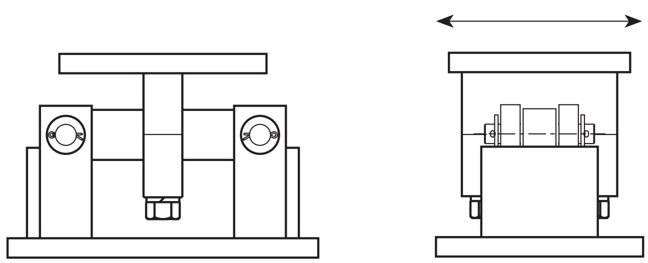


Figure 2-20

This module allows limited movement in a direction perpendicular to the longitudinal axis of the load cell.

Construction and Features

1) A rigid base plate with four cross-drilled uprights to support the pins holding the load cell.
2) A chair clamps around the load cell's center. This arrangement allows the cell freedom to slide laterally a short distance on the pins, as indicated in Figure 2-20.
3) The module is self-checking in all directions.
4) It is available in mild steel and stainless steel construction in capacities from 1,000 lb to 75,000 lb, and in cast iron from 1,000 lb to 25,000 lb. It may be used with RL75016 load cells in alloy steel or stainless steel.

Typical Application

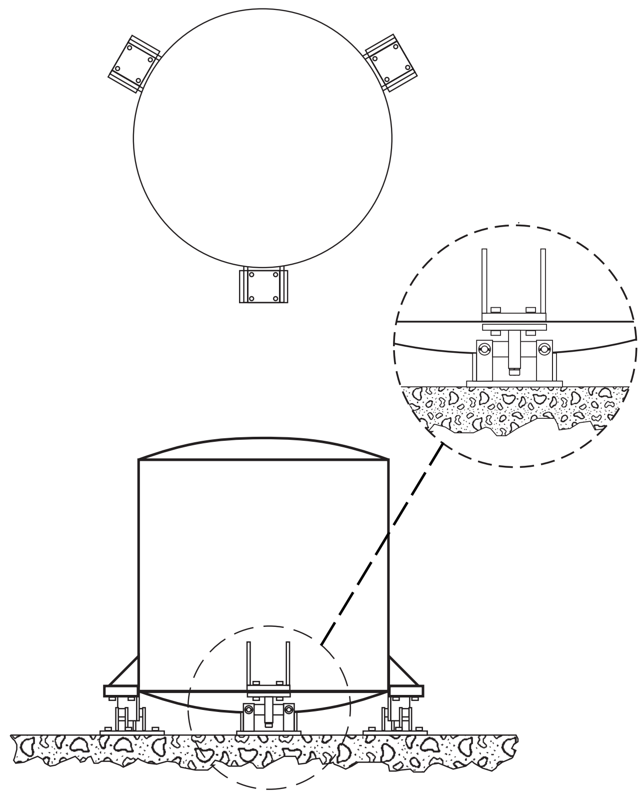


Figure 2-21: RL1600 modules on low-profile tank

SURVIVOR® 2100HE Modules

These medium- to heavy-capacity modules are available in two sizes in capacities ranging from 20,000-100,000 lb. The SURVIVOR 2100HE uses a double-ended shear beam load cell and is ideally suited for tanks, hoppers, and reactors that are subject to harsh, hostile environments. This module provides superior corrosion, moisture ingress, and mechanical protection. In the majority of applications, the assemblies are self-checking and held captive with no need for check or stay rods. The load cells are each waterproof guaranteed and NTEP certified, 1:5000 division class III, yielding up to 0.02% total error.

Allowable Movement

Figure 2-22 illustrates the 2100HE module's capability to handle movement.

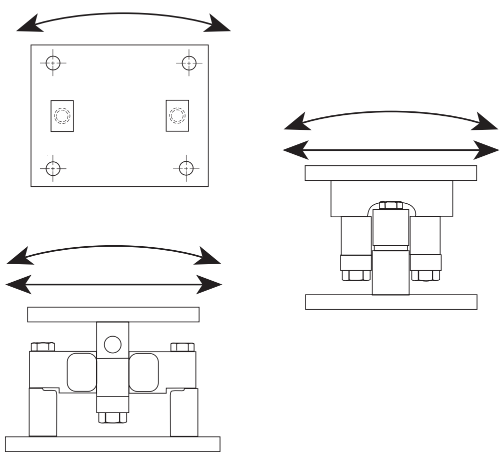


Figure 2-22: SURVIVOR 2100HE

Construction and Features

1) IP67 environmental rating is guaranteed against moisture damage.
2) Design transmits the load with a sliding pin on the load bearing groove of the cell to allow for thermal expansion/ contraction with little friction.
3) Tolerates eccentric loads and side loads of up to 100% of capacity.
4) Teflon®-lined cable is standard for high temperature and maximum chemical resistance.
5) All modules come standard in stainless steel.
6) Internal lift-off protection and checking eliminates extraneous hardware.
7) Standard conduit adaptor is included for added protection.

Typical Application

Typical applications for the SURVIVOR 2100HE include heavy-capacity tanks, blenders, reactors, and bulk inventory management.

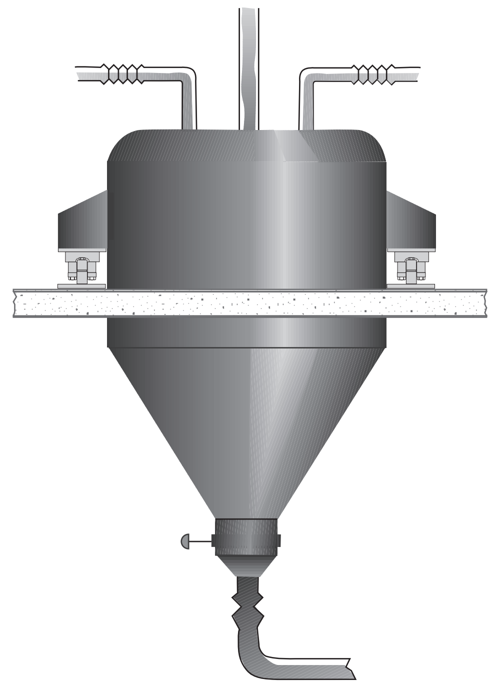


Figure 2-23: SURVIVOR 2100HE in heavy-capacity application

EZ Mount 1

In applications where substantial thermal expansion/contraction is expected, or room is not available to raise a vessel significantly for load cell replacement, the EZ Mount 1, also using a double-end, center-loaded module, is an excellent choice to handle vessel movement and limited space requirements.

The EZ Mount 1 uses a round load cell that allows the top loading plate to pivot to correct minor alignment problems. The module can also accommodate substantial movement in the direction perpendicular to the longitudinal axis of the load cell.

The load cell in the EZ Mount 1 is supported on hardened circular spacers. Screws secure it to the base plate. The top chair is held captive by removable pins on top and bottom of the load cell. This allows the load cell replacement without raising the vessel, but merely by taking the load off the module.

EZ Mount 1 modules and load cells are available in alloy steel or stainless steel in capacities from 5,000 lb to 250,000 lb.

Allowable Movement

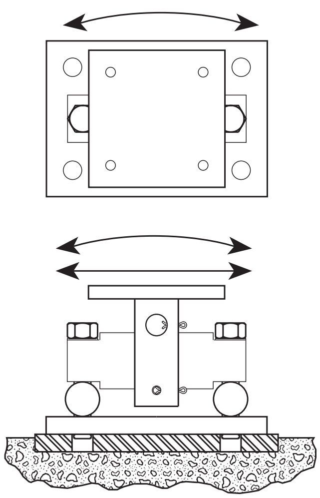


Figure 2-24

Construction and Features

1) Each end of the load cell is screwed to a base plate through a hardened cylindrical spacer which is cross drilled to allow the screw to pass through.
2) The chair assembly has a clearance hole through which the load cell passes. A hardened load pin is inserted horizontally at the top of the clearance hole which transmits the load to the cell. This pin sits in an annular groove at the center of the cell.
3) This arrangement allows the chair to move in practically all directions, as illustrated in Figure 2-24, while providing checking in all directions.
4) The load cell can be removed easily by raising the vessel only enough to relieve the load from the cell.
5) The module is available in capacities from 5,000 lb to 250,000 lb in both mild steel and stainless steel. It may be used with the alloy steel RL70000 or 5103 and the stainless steel 9103.

Typical Application

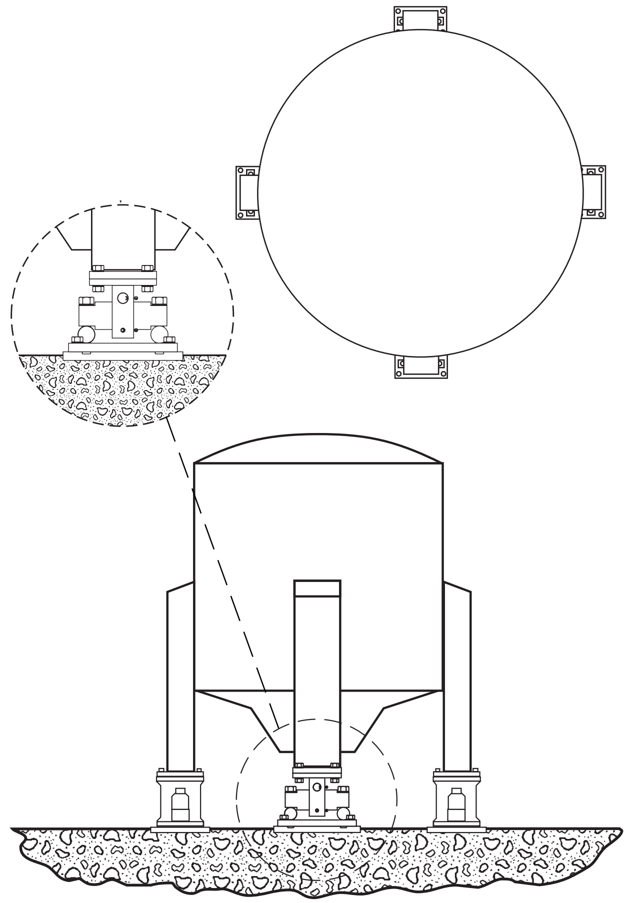


Figure 2-25: EZ Mount 1

TSA Truck Scale Modules

The TSA load cell module is used primarily for truck scales, and in certain applications for vessel weighing applications. The modules are constructed of cast iron, and are available in load cell capacities from 10,000 lb to 75,000 lb. The Unilink design provides freedom of movement in the longitudinal direction while also being self-centering, making this module ideal for vehicle scales.

Figure 2-26 illustrates the TSA module. Unlike the double-ended beams used for the RL1600 or EZ Mount 1, the TSA module should be mounted with the greatest expected movement aligned with the longitudinal axis of the load cell. In a truck scale, this is normally in the direction of truck travel.

Allowable Movement

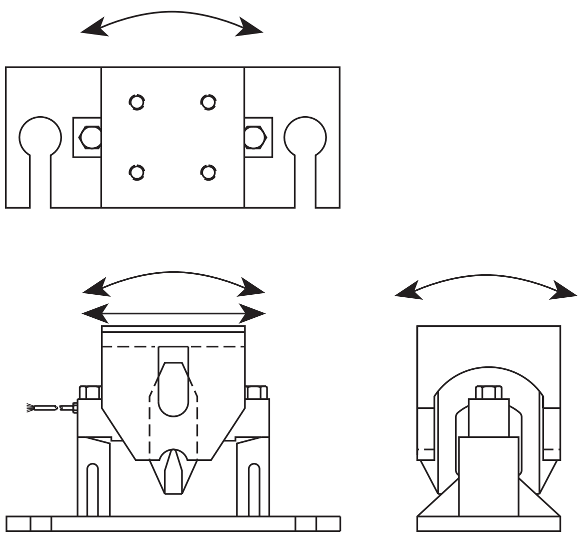


Figure 2-26

Construction and Features

1) The load cell ends are screwed to a rigid U-shaped base plate.
2) A link sits over the center of the cell which has a radiused groove at the center. The bottom of this link has two saddle blocks which project outwards. The top girder chair assembly sits on these ears.
3) The module is free to move in the directions indicated in Figure 2-26.
4) Because the load is suspended by a link, the scale is free to rock back and forth along the longitudinal axis of the load cell. Because of the pendulous action of the link, the scale will return to its original position after being displaced along the longitudinal axis of the cell.
5) When a number of modules are fastened to a deck, the modules are restrained from rocking laterally.
6) A scale using this module must be checked along the longitudinal axis of the load cell to prevent over-travel. Stay rods or bumper bolts may be used.
7) The module does not provide lift-off protection which, if required in a vessel weighing application, must be provided externally.
8) The cast iron TSA modules use the Sensortronics 65058 double-ended shear beam load cell, which is made of high alloy steel.

Typical Application

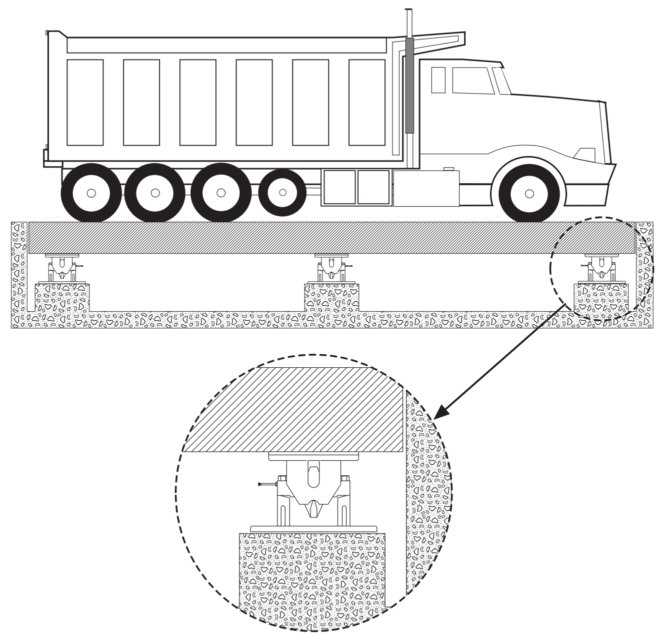


Figure 2-27: TSA modules in truck scale

Translink™ Truck Scale Modules

Self-centering mounting assemblies like the Translink are classified as compression-type mounts, yet actually apply load to their cells in a tension manner through a hanging pendulum mechanism below the load cell. The pendulum action gives them their unique self-centering ability.

The modules are commonly used to support a free-floating platform like a truck scale. The platform's horizontal float is limited by bumper pads on all sides. The deck will always return to a central position after lateral movement and not remain in contact with the bumper pads.

Unlike the other double-end beams described so far, the Translink mounting assembly uses an end-loaded shear beam that is supported by a concave or convex insert in the center that allows the cell to pivot.

Allowable Movement

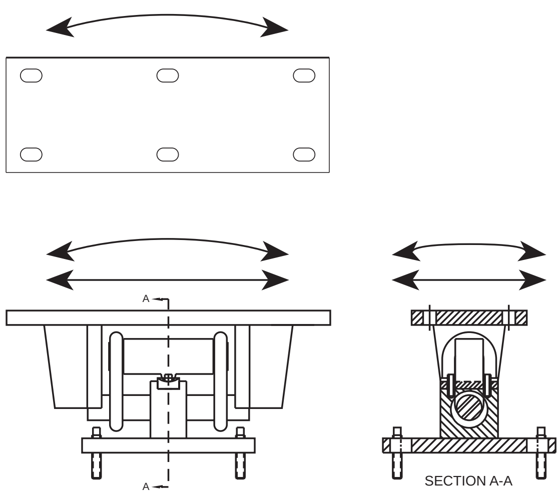


Figure 2-28

Construction and Features

1) A bridge is welded to a base plate. The bridge can accommodate a hardened convex or concave insert on which the load cell sits. Two roll pins prevent the cell from sliding sideways.
2) A forged link hangs from each end of the load cell, and they support a heat-treated load bar which passes under the bridge. The load bar has circular grooves (corresponding to the loading grooves in the load cell) in which the links sit, and the top chair sits on each end of the load bar.
3) This arrangement allows movement in all horizontal directions, as shown in Figure 2-28.
4) This module has a pendulous action which tends to return the deck to its original position after it has been disturbed longitudinally or laterally.
5) This module is ideally suited to vehicle scales or high-capacity vessel scales.
6) This module requires the scale to be checked in the horizontal plane. Stay rods may be used or, because of the self-centering action, bumper bolts are sufficient. It does not provide lift-off protection which must be provided externally if required on a vessel scale.
7) The Translink module is available in mild steel for the RL75040 or Sensortronics 65040 in capacities from 25,000 lb to 75,000 lb, and the RL75223 and RTI 5223 in capacities from 50,000 lb to 100,000 lb.

Typical Application

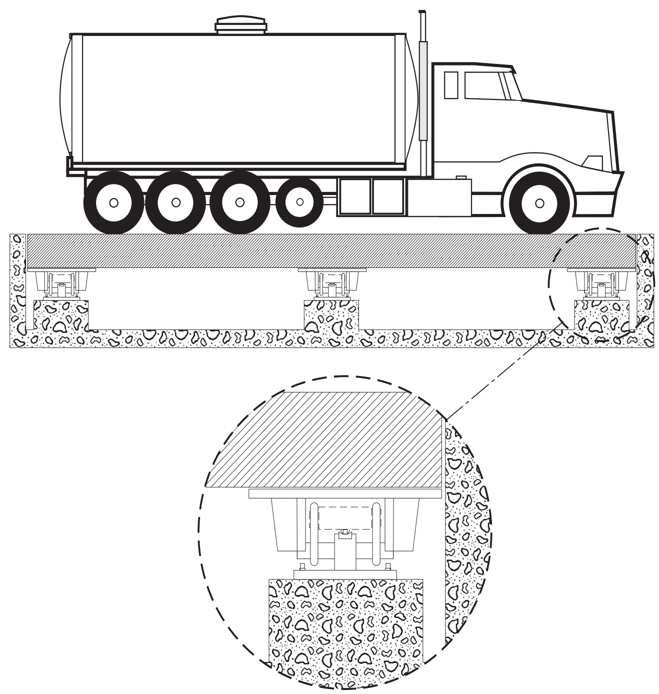


Figure 2-29

Compression Canister Load Cell Modules

Introduction

When mounts are needed in capacities over 100,000 lb, canister load cell mounts may be the only choice. These cells are good in severe conditions and have provided proven performance for decades in truck, railroad, and heavy-capacity tank applications. Available in capacities to 500,000 lb per mount assembly, most canister mounting assemblies require more complex components than mounts using beam load cells, especially if the mounts are designed to accommodate expansion.

The load is transferred to the cell through a hardened, convex load button which mates with a hardened flat loading plate. The rounded load button and flat plate tend to promote point loading, minimizing extraneous forces.

General Mounting Principles

- A compression canister should be mounted on a flat plate of sufficient thickness to prevent deflection. The foundation must be rigid.
- The load should be introduced through a spherically-radiused load button which is hardened.
- The load must be introduced vertically along the center line of the cell.
- The top plate which contacts the load button must be hardened to prevent peening of the contact point.
- Some external method of both horizontal and vertical checking may be required.

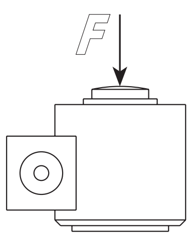


Figure 2-30

Rice Lake Weighing Systems Weigh Modules

RLC Weigh Modules

The RLC self-aligning silo mount, together with the RLC load cell family, is an ideal solution for medium capacity process control, batch weighing, silo/hopper and belt scale applications.

The RLC mount incorporates a removable rocker pin design that uses hardened stainless steel components on all load bearing surfaces. The full stainless steel construction guarantees long term reliability, even in the most harsh environments.

Allowable Movement

The RLC mount shown in Figure 2-31 tolerates controlled movement in all directions. The silo or hopper is held captive, eliminating the need for additional check rods, unless major load movement is anticipated. The unique design allows the load cell to be easily removed for replacement.

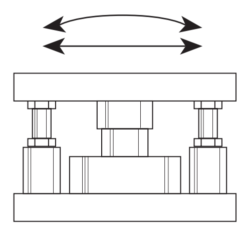


Figure 2-31

Construction and Features

1) The RLC load cell consists of three concentric rings machined from a single piece of stainless steel. The outer ring rests on the base plate. The middle ring contains four circular strain gauges. The inner ring accepts the load and deflects vertically, activating the strain gauges in the middle ring.
2) A separate loading pin fits into the load cell's inner ring and into a hardened bearing cup on the top plate of the mount. The inner ring vertical travel is limited by the base plate, providing positive overload protection at 150% of capacity.
3) The RLC ring load cell is held captive in the mount by three pins at the cell's outer circumference. To install or replace the load cell, the mount's top plate need only be raised with the integral jacking screws a fraction beyond the height of the pins.
4) The jacking screws provide lift-off protection as well as lateral self-checking capabilities to eliminate the need for check rods.

Typical Application

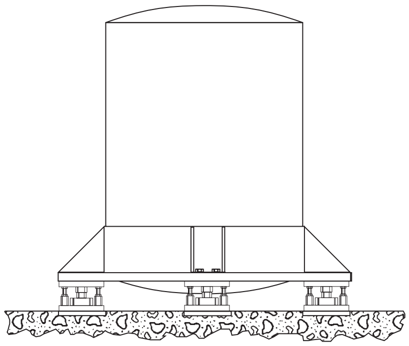


Figure 2-32: RLC Self-Aligning Silo Mount

MagnaMount® Tank, Truck & Railroad Track Mounts

Heavy-capacity vessels can be mounted successfully on large compression mounting assemblies that use heavy canister load cells. MagnaMounts, which are also used for truck and railroad scales, have capacities to 200,000 lb per mount.

These mounts are cushioned somewhat by the low-friction pads which allow the load plates to slide horizontally. The pads provide some protection from shock loading. Load cells are hermetically sealed for severe applications.

Horizontal check rods must be used with the MagnaMount. Additionally, vertical check rods may be required to provide lift-off protection.

Allowable Movement

The MagnaMount shown in Figure 2-33 allows for an unlimited amount of multidirectional movement in the horizontal plane through sliding load plates that incorporate a low-friction Teflon® surface.

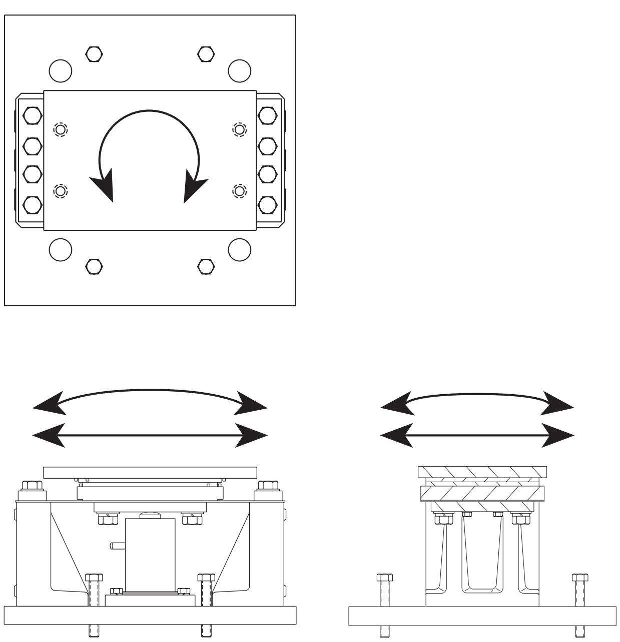


Figure 2-33

Construction and Features

1) A heavy-duty ground base plate on which the load cell is fastened. The base plate assembly is completed by two heavy-duty "L"-shaped castings, one on each side of the cell.
2) A hardened load introduction plate which rests on the cell's load button.
3) The load introduction plate and another plate sandwich a thin flexure plate which in turn is fastened at each side to the base plate assembly. This flexure is horizontal and because of the minimal deflection of the cell under load, has negligible effect on the accuracy of the scale. The flexure holds the load introduction plate rigid in a horizontal plane, thus preventing the transmission of side forces to the cell.
4) A top plate is mounted to the scale. This plate is separated from the "sandwich," described previously, by Teflon pads. This arrangement allows the top plate to move in a horizontal plane. This is particularly important on a relatively long vehicle scale.
5) This mount may be used on heavy-capacity vehicle scales (truck and railroad track) or high-capacity vessel scales. It may be used with the CP1 or CSP1 load cells in capacities from 10,000 lb to 200,000 lb.
6) This mount does not provide any checking to the scale; horizontal stay rods will certainly be required. Vertical check rods may be required for vessel scales.
7) The mount should be positioned so that the longest dimension of the flexure is oriented with the direction of traffic flow and/or in the direction of maximum thermal expansion/ contraction.

Typical Application

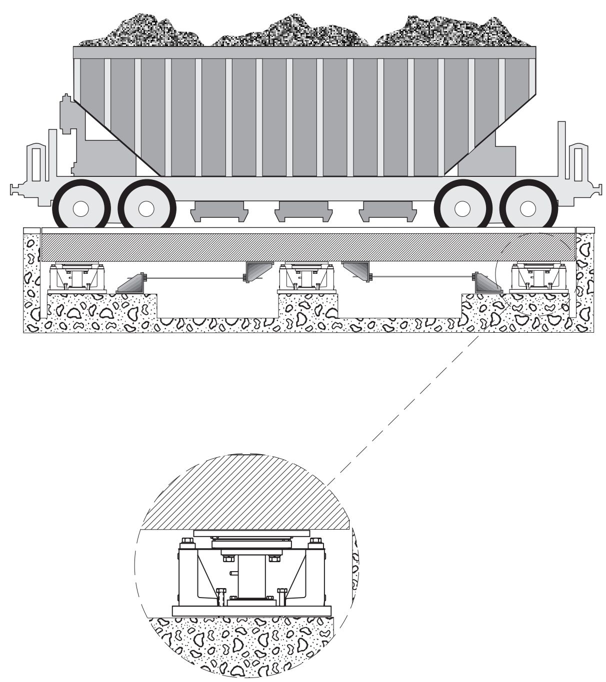


Figure 2-34: MagnaMount canister mounts

65092 Tank Mounts

The low-profile 65092 TWA module is available in capacities from 50,000 to 500,000 lb. This unique canister load cell module is not designed to accommodate as much thermal expansion movement as the MagnaMount, but it has the advantage of being self-checking, so check rods are not required to restrain lateral movement. The module will tolerate side loading up to 30% of load cell capacity and also provides lift-off protection.

Allowable Movement

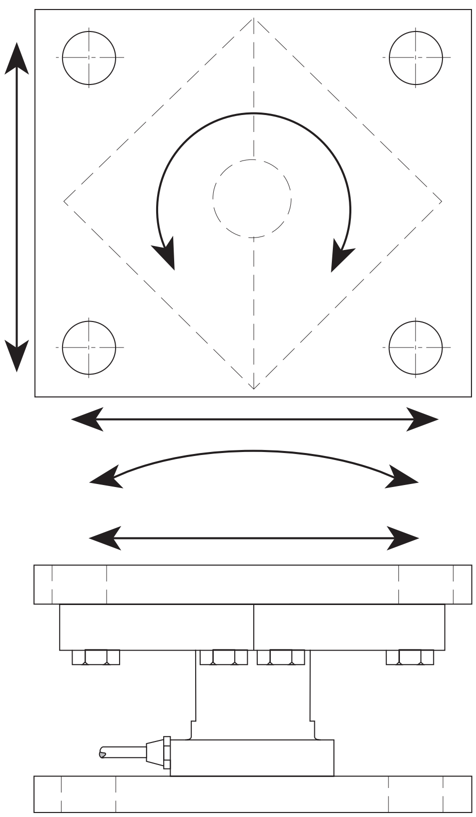


Figure 2-35

Construction and Features

1) The canister load cell is screwed to the base plate of the mount with four screws through the base plate and into the lower mounting flange of the load cell.
2) The base plate mounts directly to the foundation or structural support surface.
3) The rounded load button contacts the bottom of the hardened top loading plate. The top loading plate can be bolted directly to the vessel.
4) An upper flange on the load cell is gripped by a collar on the two triangular-shaped plates which hold the top loading plate on the load cell.
5) This arrangement allows the top loading plate to float freely on the load button for thermal expansion, yet provides side checking and lift-off capabilities.
6) The mount comes standard with nickel-plated alloy steel load cells from 50,000 to 500,000 lb. High temperature load cells are also available.
7) The mount is also available in 304 stainless steel.

Typical Application

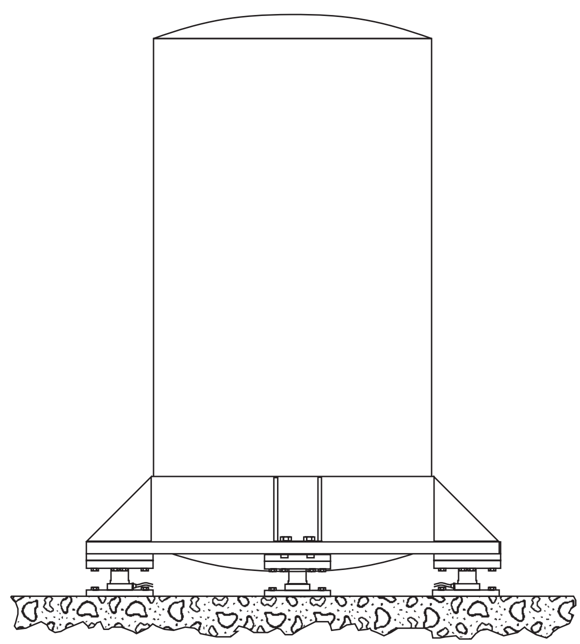


Figure 2-36: 65092 TWA canister modules

S-Beam Load Cell Modules

Introduction

Suspension mounting with tension S-beam load cells is often used for light to medium vessels where an existing overhead structure may be used to suspend the vessel.

General Mounting Principles

Figure 2-37 illustrates the correct way to apply load to an S-beam load cell.

1) The surface from which the cell is suspended should be rigid and provide minimal deflection under loads.
2) The entire suspension should be as long as possible with the load cell placed approximately at the center.
3) The center line of the top and bottom rods should pass through the load cell's load holes. The center line through the assembly should be vertical.
4) The load cell cable should emerge from the fixed end of the cell so that it does not affect accuracy.
5) The extremities of the suspension should be attached to the structure and vessel in such a manner that they are free to move. At a minimum, use spherical washer set as illustrated in Figure 2-37.
6) Use a suitable hardware assembly such as eye bolts or the ITCM system at the load cell to minimize the transmission of extraneous forces.

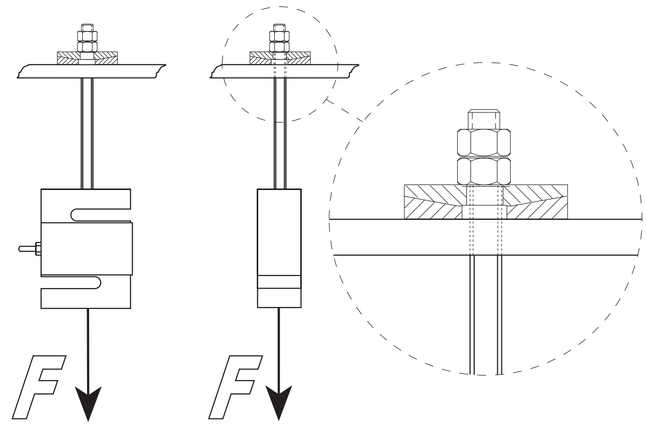


Figure 2-37

Rice Lake Weighing Systems Weigh Modules

ITCM Mounts

The ITCM assembly is a particularly convenient method of suspending a weigh vessel. The combination of clevises and rod end ball joints ensures that forces detrimental to accurate system performance are isolated from the load cell. In addition, the unique electrical isolation provided to the load cell by this assembly helps prevent damage from stray currents.

Allowable Movement

Figure 2-38 illustrates the use of the ITCM weigh module. This mounting arrangement prevents most of the potential problems caused by extraneous forces acting on S-beam load cells.

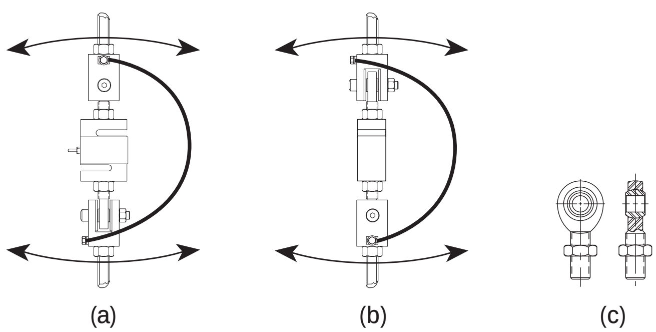


Figure 2-38

Construction and Features

1) The ITCM consists of a high-precision rod end ball joint which is screwed into each end of the S-beam. The rod end ball joint has a "ball" which is free to rotate in a TFE bearing; see Figure 2-38 (c). A clevis is attached to the rod end ball joint using a shoulder screw.
2) This arrangement provides excellent alignment between the center lines of the rods and the center line through the cell's load holes.
3) This arrangement allows movement in the directions indicated by the arrows and also allows rotation, thus ensuring that extraneous forces are not transmitted to the load cell.
4) The ITCM also incorporates an insulating system which will not allow the flow of stray currents through the load cell. The parallel ground strap provides further protection with an alternate path to ground.
5) ITCM's are available in mild steel in capacities from 100 lb to 20,000 lb using the RL20000 load cell.

NOTE: A single ITCM is often used to convert a mechanical truck or hopper scale to electronics. This allows you to take advantage of process control or data collection options available with electronic weighing. The conversion can be accomplished by inserting an ITCM assembly in the steelyard rod without affecting the operation of the mechanical beam or dial which may be retained as a backup.

Typical Applications

Figure 2-39 illustrates what is perhaps the simplest weigh vessel. This works well under the following conditions:

- Weighing self-leveling materials only.
- The vessel is symmetrical about the point of suspension so that the center of gravity rises along the same vertical line each time.

These restrictions ensure that the content's center of gravity is always vertically below the load cell, removing the tendency of the vessel to bind against the bumpers. Bumpers are provided to limit the amount of sway produced if the tank were accidentally hit or subjected to other external forces. Bumpers can only be used with a self-centering vessel mounting arrangement, since the vessel cannot remain in contact with bumpers without causing weight reading errors. The vessel must also be restrained from rotating to prevent suspension hardware from unscrewing.

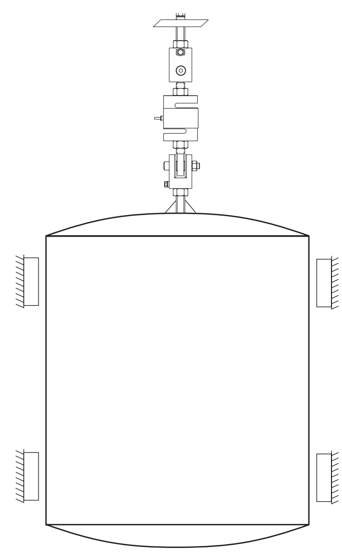


Figure 2-39

A weigh vessel suspended from a single load cell may be used to weigh solids if horizontal stay rods are used to eliminate the side movement caused by shifts in the content's center of gravity. This is discussed further in the *Vessel Restraints* section.

The three load cell suspension system shown in Figure 2-40 uses three S-beam load cells placed 120° apart on a cylindrical vessel. This avoids the problems of having to adjust the weight carried by each cell, as the inherent stability of a 3-point hanging system will ensure equal loading at each point. To ensure stability, suspension rods should be attached to the vessel at or above the center of gravity of the filled vessel. Though this configuration is inherently stable, special attention is required when significant vibration, agitation, wind or seismic activity are possible. In this case, bumpers or horizontal check rods should also be employed.

Each support point should be equally rigid and deflect by the same amount when loaded. If not, the load may be transferred unequally, which may overload one or more of the cells.

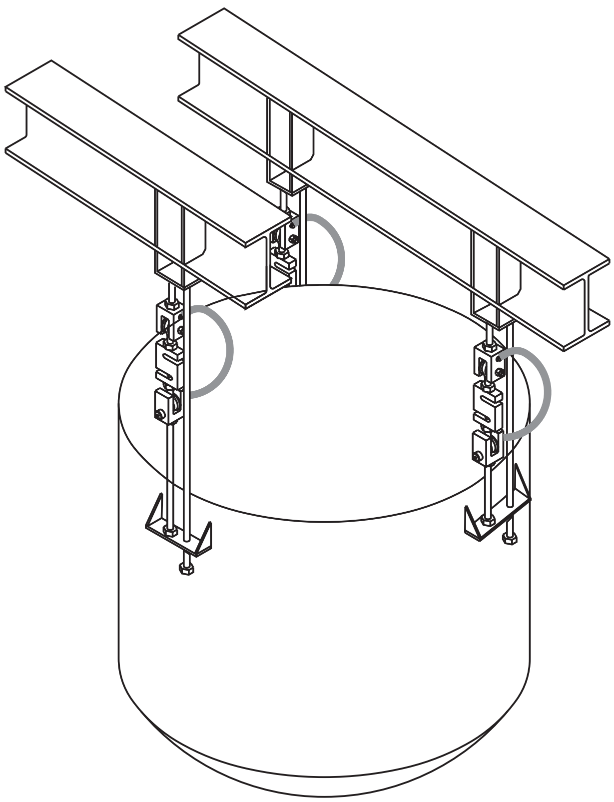


Figure 2-40

The 4-cell suspension system shown in Figure 2-41 is most common for rectangular hoppers. As mentioned previously, adjustment will be necessary to equalize the load carried by each load cell to within 10% of each other.

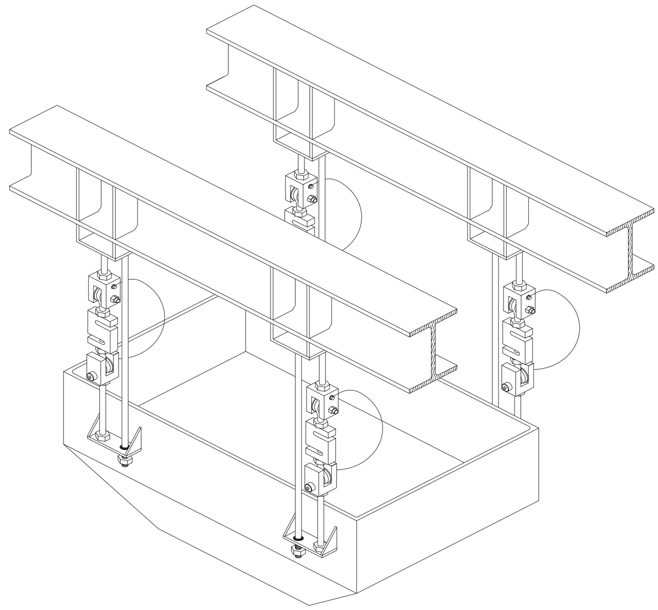


Figure 2-41

⚠ Caution Note the use of safety check rods in the suspension mount illustrations. Each rod passes through a large clearance hole at the lower end and the nuts are loose so there is no interference with the weighing accuracy. All suspended vessel weighing systems must be protected by safety check rods or chains to prevent damage or injury in the event of a failure. See more detailed information on vessel safety restraint systems in Section 4.

Mounting Assemblies and Compatible Load Cells

Mounting Assembly	Type	Capacity Range	Material	Finish	Recommended Checking	Load Cell Type
ITCM RL20000	Tension	25-20,000 lb	Mild Steel	Zinc Plate	Stay rods or bumpers	S-Beam
ITCM RL20001	Tension	250-20,000 lb	Mild Steel	Zinc Plate	Stay rods or bumpers	S-Beam
RL50210 TA	Compression	50-250 lb	Mild Steel	Zinc Plate	Minimal Self Checking	Single-ended beam
RL50210 TA	Compression	500-2,500 lb	Mild Steel	Zinc Plate	Minimal Self Checking	Single-ended beam
RL50210 TA Stainless Steel	Compression	500-2,500 lb	304 Stainless Steel	—	Minimal Self Self Checking	Single-ended beam
RL1800	Compression	250-10,000 lb	Mild Steel	Zinc Plate	Self Checking	Single-ended beam
RL1800 Stainless Steel	Compression	250-10,000 lb	304 Stainless Steel	—	Self Checking	Single-ended beam
RL1900	Compression	1,000-10,000 lb	304 Stainless Steel	—	Self Checking	Single-ended beam
RLC	Compression	500-5,000 kg	304 Stainless Steel	—	Self Checking	Canister
Paramounts®	Compression	225-22,500 lb	Mild Steel	Zinc Plate	Self Checking	Single-ended beam
Paramounts® Stainless Steel	Compression	225-22,500 lb	304 Stainless Steel	—	Self Checking	Single-ended beam
RL1600 Cast Iron	Compression	1,000-25,000 lb	Cast Iron	Zinc Plate	Self Checking	Double-ended beam
RL1600 Mild Steel	Compression	1,000-75,000 lb	Mild Steel	Zinc Plate	Self Checking	Double-ended beam
RL1600 Stainless Steel	Compression	1,000-75,000 lb	304 Stainless Steel	—	Self Checking	Double-ended beam
EZ Mount 1	Compression	5,000-250,000 lb	Mild Steel	Painted	Self Checking	Double-ended beam
EZ Mount 1 Stainless Steel	Compression	5,000-150,000 lb	304 Stainless Steel	—	Self Checking	Double-ended beam
Translink™ RL75040A	Compression	25,000-75,000 lb	Mild Steel	Painted	Stay rods or bumper bolts	Double-ended beam
Translink™ RL75223	Compression	50,000-100,000 lb	Mild Steel	Painted	Stay rods or bumper bolts	Double-ended beam
TSA	Compression	10,000-75,000 lb	Cast Iron	Painted	Stay rods or bumper bolts	Double-ended beam
MagnaMount™	Compression	10,000-200,000 lb	Mild Steel/ Cast Iron	Painted	Stay rods	Canister
65092 TWA	Compression	50,000-500,000 lb	Alloy Steel	Zinc Plate	Self Checking	Canister

Compatible Load Cells

Mount	Compatible Load Cells	Range	NTEP	Material	Finish	Protection	Matched Output	Comments
ITCM	RL20000	25-20,000 lb	Yes	Alloy Steel	Chrome over Nickel	Environmental	—	Used for suspended tank, hopper and vessel weighing, and electromechanical conversion.
RL20000	RL20000SS	50-10,000 lb	No	Stainless Steel	—	Environmental	—	
	363	50-10,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	9363	50-10,000 lb	Yes	Stainless Steel	—	Environmental	—	
ITCM	RL20001	250-20,000 lb*	Yes	Alloy Steel	Nickel Plate	Environmental	—	
RL20001	60001	250-20,000 lb*	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	60050	250-20,000 lb*	No	Stainless Steel	—	Environmental	—	
RL50210 TA	RL50210	50-250 lb	No	Alloy Steel	Nickel Plate	Environmental	—	
	60040	50-250 lb	No	Alloy Steel	Nickel Plate	Environmental	—	
RL50210 TA	RL30000	250-2,500 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	Used for low-capacity tank weighing, conveyor and deck scales. Neoprene pad provides shock protection but minimal self-checking capabilities.
	RL39123	250-2,500 lb	No	Stainless Steel	—	Environmental	—	
	RL35023	500-2,500 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	RL39523	1,000 & 2,500 lb	No	Stainless Steel	—	Hermetic	—	
	RL35083	1,000 & 2,500 lb	No	Stainless Steel	—	Hermetic	—	
	5123	1,000 & 2,500 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	9123	1,000 & 2,500 lb	No	Stainless Steel	—	Environmental	—	
	65023-0107	500-2,500 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	65023-0113	500-2,500 lb	No	Stainless Steel	—	Environmental	—	
	65083	1,000-2,500 lb	No	Stainless Steel	—	Hermetic	—	
	BLC-10100	1,000-2,500 lb	Yes	Stainless Steel	—	Environmental	—	
RL1800	RL30000	250-10,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	Used for low- to medium-capacity tank, hopper and vessel weighing.
	RL39123	250-10,000 lb	No	Stainless Steel	—	Environmental	—	
	RL35023	1000-10,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	RL39523	1,000-10,000 lb	No	Stainless Steel	—	Hermetic	—	
	RL35083	1,000-10,000 lb	No	Stainless Steel	—	Hermetic	—	
	5123	1,000-10,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	9123	1,000-10,000 lb	No	Stainless Steel	—	Environmental	—	
	65023-0107	1000-10,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	65023-0113	1000-10,000 lb	No	Stainless Steel	—	Environmental	—	
	65083	1,000-10,000 lb	No	Stainless Steel	—	Hermetic	—	
	BLC-10100	1,000-5,000 lb	Yes	Stainless Steel	—	Environmental	—	
RL1900	SSB	1,000-10,000 lb	Yes	Stainless Steel	—	Hermetic	—	Used for low- to medium-capacity tank, hopper and vessel weighing.
	SB3	1,000-10,000	No	Alloy Steel	Nickel Plate	Environmental	—	
RLC	RLC	500-5,000 kg	No	Stainless Steel	—	Hermetic	—	Used for low- to medium-capacity tank, bin and hopper weighing.
Paramounts®	SB4	225-22,500 lb (1-100KN)	Yes	Stainless Steel	—	Hermetic	Yes	Used for high-capacity tank, hopper and vessel weighing.
RL1600	RL75016	1,000-75,000 lb	No	Alloy Steel	Nickel Plate	Environmental	—	Used for low- to high-capacity tank, hopper and vessel weighing.
	65016	1,000-75,000 lb	No	Alloy Steel	Nickel Plate	Environmental	—	
	RL75016SS	1,000-75,000 lb	No	Stainless Steel	—	Environmental	—	
	65016-0104	1,000-75,000 lb	No	Stainless Steel	—	Environmental	—	
EZ Mount 1	RL70000	5,000-100,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	Used for high-accuracy medium- to high-capacity tank, hopper and vessel weighing.
	5103	5,000-250,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
	9103	5,000-150,000 lb	No	Stainless Steel	—	Environmental	—	
Translink™ RL75040A	RL75040A	25,000-75,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	Used for livestock and vehicle scales and high-capacity tank scales.
	65040	25,000-75,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
Translink™ RL75223	RL75223	50,000-100,000 lb	Yes	Alloy Steel	Nickel Plate	Hermetic	—	
	5223	50,000-100,000 lb	Yes	Alloy Steel	Nickel Plate	Hermetic	—	
TSA	65058	10,000-25,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	Used for livestock, vehicle scales and high-capacity tank scales.
		50,000-75,000 lb	Yes	Alloy Steel	Nickel Plate	Environmental	—	
MagnaMount™	CP1	10,000-200,000 lb	No	Alloy Steel	Epoxy Paint	Hermetic	—	Used for high capacity vehicle scales including railroad track. Also used for high-capacity tank scales.
	CSP1	10,000-200,000 lb	Yes	Alloy Steel	Epoxy Paint	Hermetic	—	
65092 TWA	65094	50,000-500,000	No	Alloy Steel	Nickel Plate	Environmental	—	Used for high-capacity tank and silo weighing

*Excluding 15,000 lb

VESSEL ATTACHMENTS

Attaching Piping to Weigh Vessels

Without question, attached piping is by far the largest source of error in vessel weighing. Hence the piping arrangement must be carefully planned in the design of any weigh vessel.

Figure 3-1 shows a vessel mounted on load cells and supported on an I-beam structure. An attached horizontal pipe is rigidly supported a distance "*l*" from the vessel.

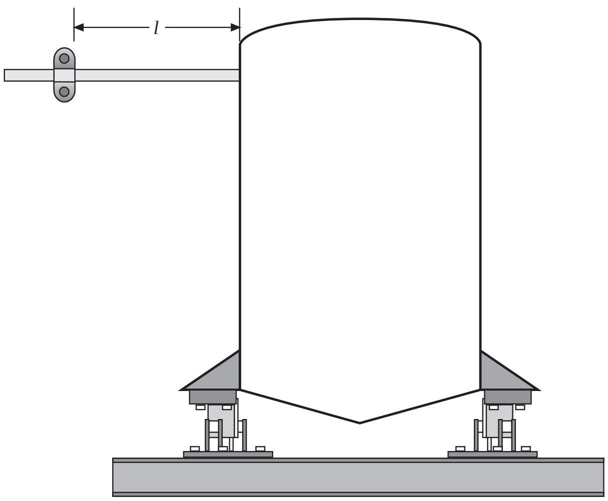


Figure 3-1

When the vessel is loaded, it moves downward as shown in Figure 3-2 as a result of:

1) The deflection of the load cell (.005" to .015" at full load), and
2) The deflection of the support structure.

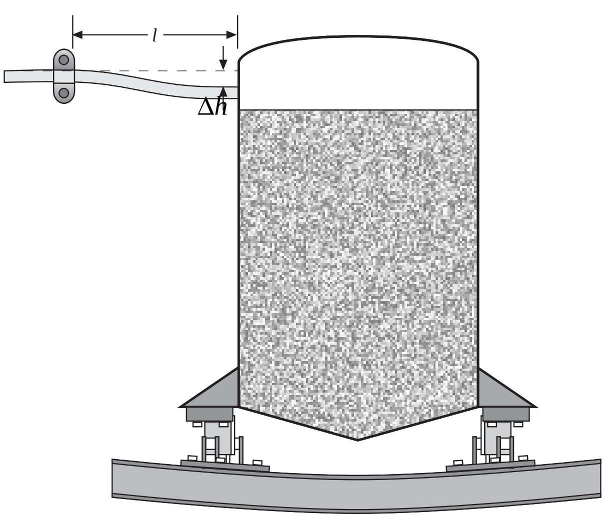


Figure 3-2

The attached pipe also deflects downward by the same amount Δh and it applies an upward force, F_1, to the tank.

The effects of piping are particularly severe when several pipes are attached to a low-capacity weigh vessel. Through proper design, the upward forces exerted by the pipes can be reduced to a small percentage of the vessel's live load. Then, by calibrating the vessel with weight, the remaining effects can be compensated for. Calibration using a load cell simulator will not produce accurate results, since there is no way to simulate the effects of attached piping (see *Calibrating Vessel Weighing Systems* in Section 4 for further details).

Some common rules of thumb for piping design are as follows:

- reduce deflection of the vessel support structure to a minimum.
- use the smallest diameter, lightest wall pipe possible.
- all pipes must run horizontally away from the vessel.
- place the first pipe support 20 to 30 times the pipe diameter away from the vessel (for example, for a 2" diameter pipe, the first support would be placed at least 40", and preferably 60", away from the vessel).

NOTE: Pipe diameters and wall thickness, pipe support intervals, etc., must be chosen consistent with the functionality, structural, and reliability requirements of the system in addition to recommendations of this section.

For a more rigorous treatment of the subject, the force F_1 exerted

$$F_1 = \frac{.59(D^4 - d^4) \text{ x } (\mathrm{D}h) \text{ x } E}{l^3}$$

on the vessel may be calculated using the following equation:

where:

D = outside diameter of pipe

d = inside diameter of pipe

Δh = total deflection of the pipe at the vessel relative to the fixed point.

E = Young's modulus
= 29,000,000 for mild steel
= 28,000,000 for stainless steel
= 10,000,000 for aluminum

l = length of pipe from the vessel to the first support point.

This yields conservative results, since it assumes that the pipe is held rigidly at both ends. In practice there will be some give in both the support point and its attachment to the vessel. The example on the following page illustrates the use of this formula.

Example I

A steel tank is supported on load cells and a steel structure with deflections of .008" and .250" respectively under load. A 4" schedule 40 pipe is attached horizontally with 36" free span between the vessel and the first support point. What force F_1 is exerted upward on the vessel?

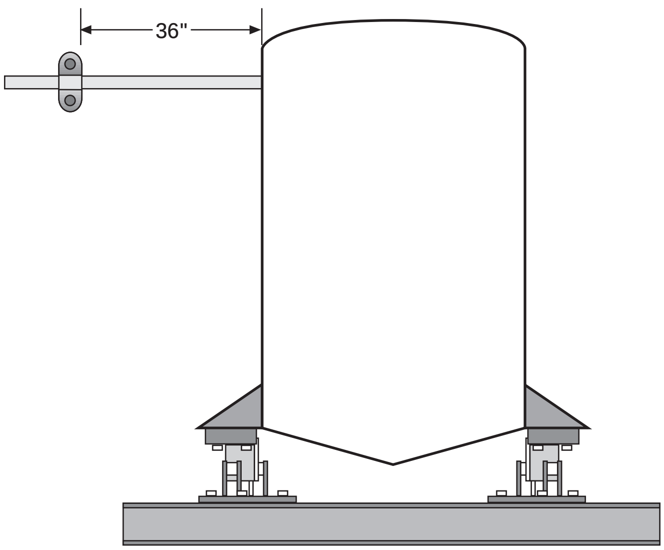


Figure 3-3

From the above information:

Δh = .008" + .250" = .258"

E(steel) = 29,000,000

For schedule 40 pipe, D = 4.50, d = 4.03

l = 36"

hence:

$$F_1 = \frac{.59(4.50^4 - 4.03^4) \times .258 \times 29{,}000{,}000}{36^3}$$

$$= 13{,}840 \text{ lb.}$$

The first line of Table 1 (Example 1) summarizes the above result. The other lines (Examples 2–5) represent the result when one parameter is changed. The last column on the right expresses the % change in F_1 relative to Example 1 (13,840 lb).

Example 2 shows the effect of doubling the length of pipe between the vessel and first support point. The 87% reduction shows that F_1 can be greatly decreased by increasing the distance to the first support point.

Example 3 shows the effect of cutting the structural deflection in half from .250" to .125" (the load cell deflection of .008" remains the same). It is obvious from the 48% reduction in Table 1 that F_1 can be moderately decreased by reducing the vessel's deflection.

Example 4 shows the effect of using a lighter-wall schedule 10S pipe instead of schedule 40.

Example 5 shows the effect of reducing the size of the pipe from 4" schedule 40, to 2" schedule 40. From the large 93% reduction, it is clear why you should always use the smallest diameter pipe suitable for the application.

These and other Do's and Don'ts are summarized in the *Piping Guidelines* section. Note that while the emphasis here is on attached piping, these recommendations apply equally to attached electrical conduit and cables.

If several pipes are attached to a vessel, the vertical force exerted on the vessel can be calculated for each individually, as described above, then added together to get the total force F acting vertically on the vessel. That is:

$$F = F_1 + F_2 + F_3 \ldots$$

where F_1 is the force exerted by pipe 1, F_2 the force exerted by pipe 2, etc.

Accepted practice in the scale industry for ensuring that piping does not adversely affect the required accuracy is to ensure that the following relationship is satisfied:

F ≤ .1 x system accuracy (in%) x live load (lb)

Table 1

Example	Pipe	Pipe Length(l)	Deflection(Δh)	Upward Force(F_1)	Percentage Reduction in (F_1)
1	4" schedule 40	36"	.258	13,840	---
2	4" schedule 40	72"	.258	1,730	87%
3	4" schedule 40	36"	.133	7,130	48%
4	4" schedule 10S*	36"	.258	7,630	45%
5	2" schedule 40†	36"	.258	976	93%

* For 4" Schedule 10S, D=4.50, d=4.26

† For 2" Schedule 40, D=2.38, d=2.16

For example, if a vessel's live load is 50,000 lb and a system accuracy of .25% is required, then

$F \leq .1 \times .25 \times 50{,}000$

$F \leq 1{,}250$ lb.

i.e., the sum of all vertical pipe forces must be less than or equal to 1,250 lb.

Example II:

The vessel shown in Figure 3-4 has the following characteristics:

- 40,000 lb live load
- mounted on 4 each 20,000 lb single-ended beams with full scale deflections of .010"
- structure deflection of .375"
- accuracy requirement of 0.5%
- material is stainless steel throughout

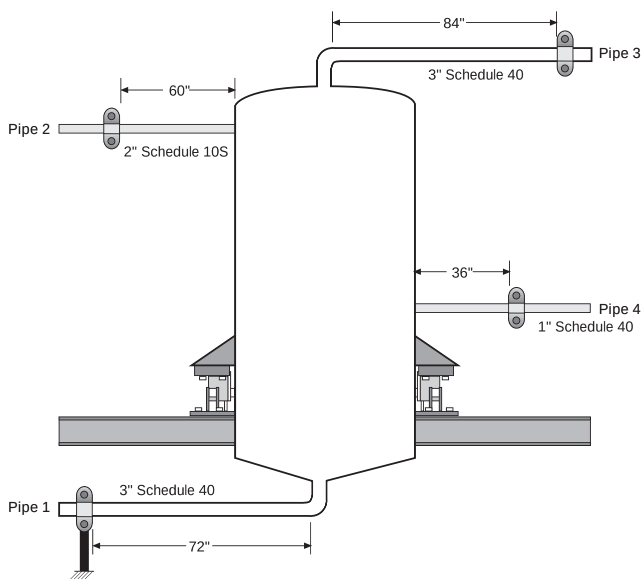


Figure 3-4

Step 1

Determine allowable F value from equation 2,

$F \leq .1 \times \text{system accuracy (\%)} \times \text{live load (lb)}$

$F \leq .1 \times 0.5 \times 40{,}000$

$\leq 2{,}000$ lb

The sum of all vertical pipe forces must be less than or equal to 2,000 lb.

Step 2

Determine total deflection. Since the live load represents only 1/2 of the load cell capacity, the load cell deflection will be

$$\frac{.010}{2} = .005"$$

Total deflection Δh = load cell deflection + structure deflection

= .005 + .375

= .380"

Step 3

Determine F_x for each pipe using the formula:

$$F_x = \frac{.59(D^4 - d^4) \times (\mathrm{D}h) \times E}{l^3}$$

a) $$F_1 = \frac{.59(3.50^4 - 3.07^4) \times .380 \times 28{,}000{,}000}{72^3}$$

= 1,029 lb.

b) $$F_2 = \frac{.59(2.375^4 - 2.07^4) \times .380 \times 28{,}000{,}000}{60^3}$$

= 391 lb.

c) $$F_3 = \frac{.59(3.50^4 - 3.07^4) \times .380 \times 28{,}000{,}000}{84^3}$$

= 648 lb.

d) $$F_4 = \frac{.59(1.315^4 - 1.049^4) \times .380 \times 28{,}000{,}000}{36^3}$$

= 239 lb.

Step 4

Determine F using the formula: $F = F_1 + F_2 + F_3 + F_4$

F = 1,029 + 391 + 648 + 239 = 2,307 lb

Since F calculated for the vessel is greater than the value determined in Step 1, this is not acceptable. There are several solutions.

1) Accept a lower accuracy (perhaps 1%, instead of .5%).
2) Reduce the deflection of the support structure.
3) Improve the piping by:
   a) using smaller, lighter pipes
   b) use flexible hose or bellows
   c) increase the distance to the first pipe support points

If we apply 3 above to this vessel then we would focus our attention on the main offender, pipe 1. The problem can be solved simply by increasing the distance to the first support from 72" to 82", yielding an F1 = 697 lb. Hence, F = 697 + 391 + 648 + 239 = 1,975 lb.

This is less than 2,000 lb, so the design is now acceptable.

Piping Guidelines

Table 2
PIPING GUIDELINES

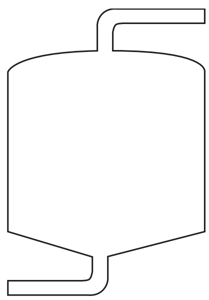
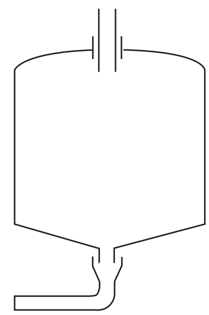
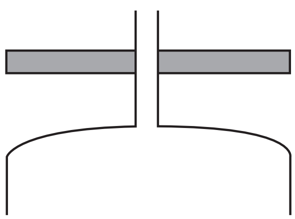
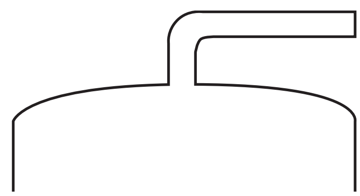
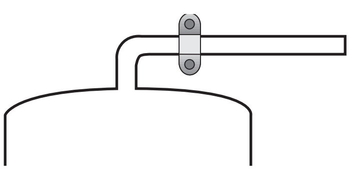
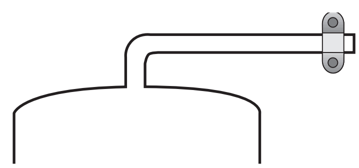
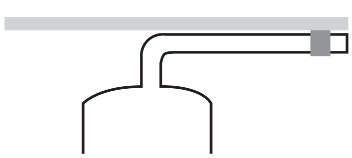
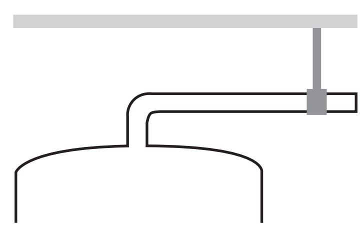
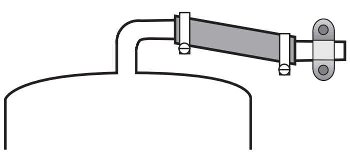
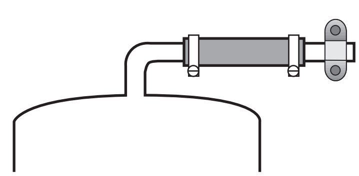
INCORRECT		CORRECT
	Do not attach pipes directly to the vessel if possible (vented systems). Allow them to enter through large clearance holes. Flexible boots may be used to seal out dust if necessary.	
	Do not run an attached pipe vertically to its first support point. This will suspend the vessel and destroy accuracy. All pipes should be run horizontally away from the vessel.	
	Increase as much as possible the distance between the vessel and the first pipe support.	
	Avoid long vertical runs of pipe when possible, particularly when they are restrained from movement in the vertical direction. This is because any thermally-induced expansion/contraction of the vertical pipe will be translated into detrimental vertical forces on the vessel, directly affecting accuracy.	
	Use flexible hose to make the connection to the vessel if possible. Do not use the flexible hose to compensate for an initial offset in the pipes.	

Table 2
PIPING GUIDELINES

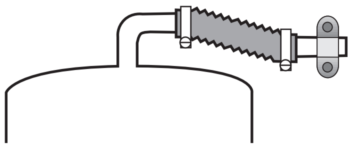
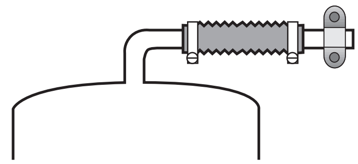
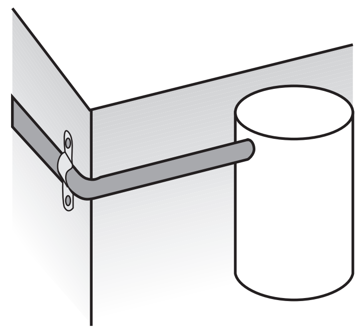
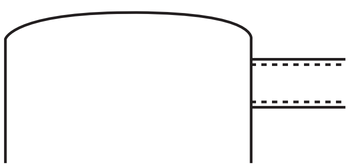
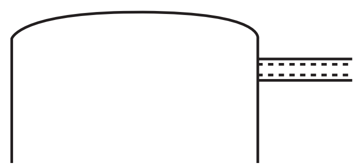
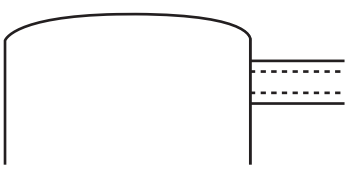
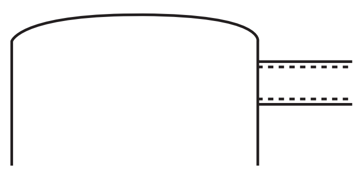
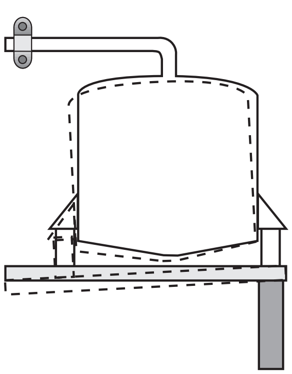
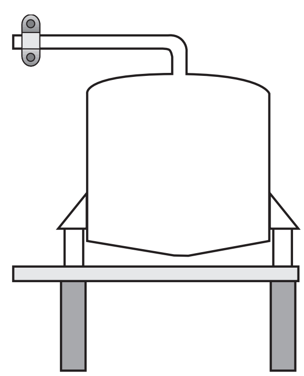
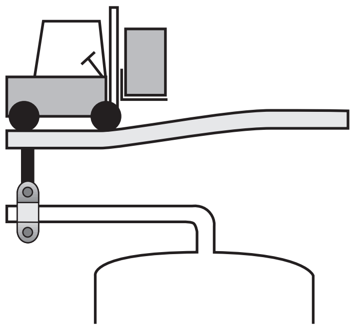
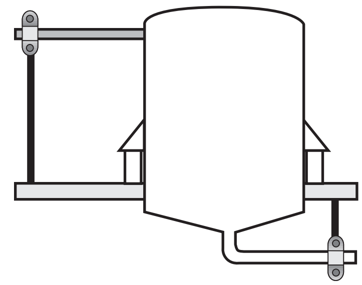
INCORRECT		CORRECT
	Use flexible bellows to make the connection to the vessel, if possible. Do not use the bellows to compensate for an initial offset in the pipes. Two bellows may be used in series where large deflections must be accommodated.	
	Placing a right angle bend in the pipe in a horizontal plane greatly reduces the stiffness of the pipe.	
	Use the smallest diameter pipe suitable for the application.	
	Use the lightest wall pipe suitable for the application.	
	Avoid tilting of the weigh vessel as a result of nonuniform support stiffness. Small rotations of the vessel can be amplified into large movements at the first support.	

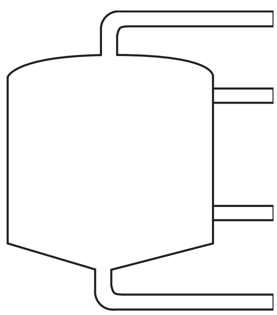
Table 2
PIPING GUIDELINES

INCORRECT | **CORRECT**

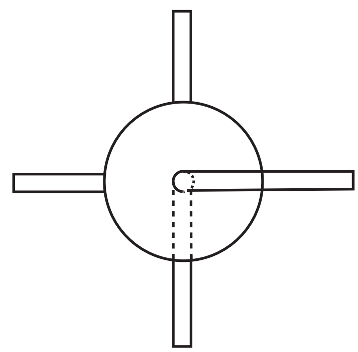


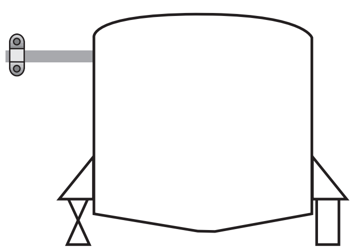
Do not support pipes on a structure which may deflect independently of the vessel. Do support pipes from the vessel's support structure so that the support point moves with the vessel, thus reducing the relative deflection.



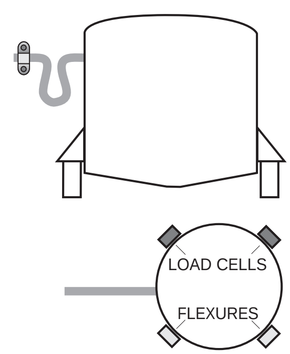


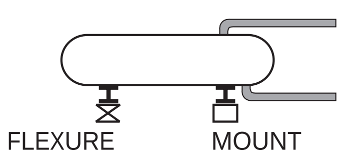
Do not attach all pipes to the same side of the vessel. Arrange them symmetrically around its diameter, as far as possible.



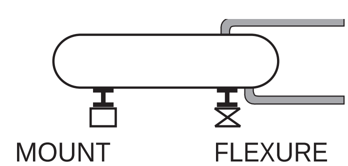


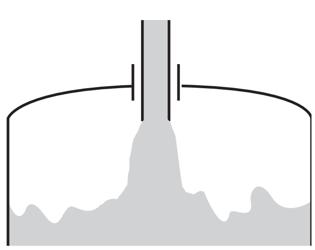
When attaching pipes to a vessel partially mounted on flexures, extra care must be exercised to avoid side forces induced by thermal expansion/contraction of the pipes. Use flexible hose, bellows, or a loop, and attach the pipes relative to the load cells/flexures, as shown, to minimize the transfer of weight from the flexures to the cells or vice versa.





With horizontal vessels partially mounted on flexures, do not attach pipes at the live end. Attach pipes over the flexures if possible, since any vertical forces exerted there are not "seen" by the load cells.





Fill pipes for liquids should enter horizontally so that impingement of in-flight material has minimal effect on the weight reading.

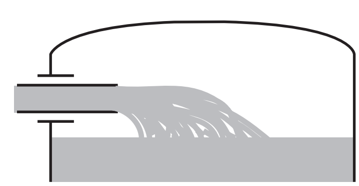
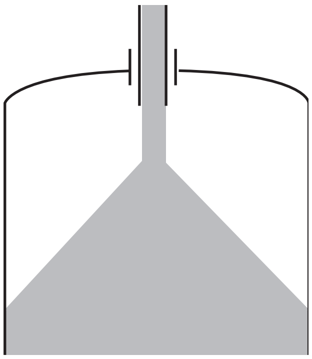
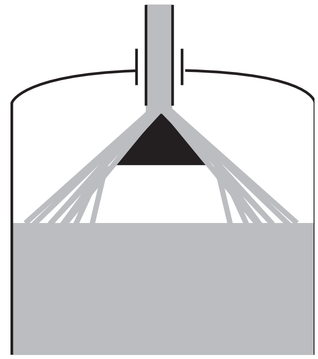
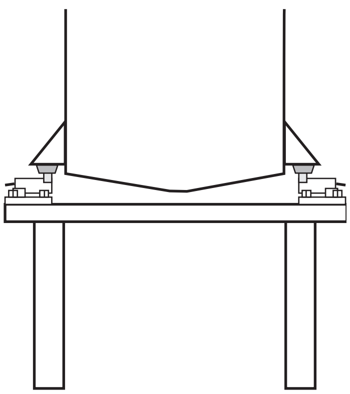
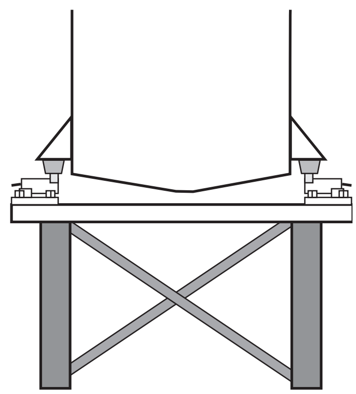
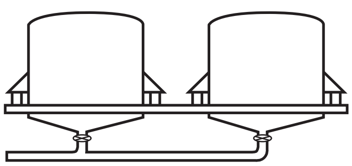
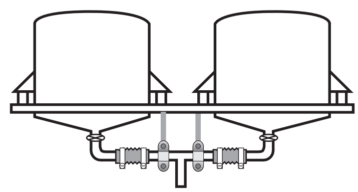
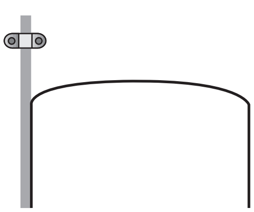
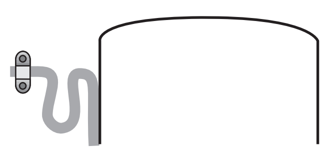


Table 2
PIPING GUIDELINES

INCORRECT		CORRECT
	With granular materials, fill the vessel symmetrically. Use a deflector cone to help distribute/level the material.	
	Do not use rubber pads or other devices which will increase the deflection of the vessel under load. Strengthen the support structure to reduce deflection.	
	Do not allow a common discharge pipe to hang directly from the vessels. In the example at left, discharging tank B will temporarily add weight to tank A. For a better installation, support the pipes independently.	
	Flexible electrical cables should not run vertically to a weigh vessel; they should run horizontally or provide a loop as shown.	

Vessel Restraint Systems

While many of the mounting arrangements offered in this guide are self checking, there are situations where additional vessel restraints may be required to steady a vessel subjected to constant vibration, or to restrain a vessel from toppling or falling in the event of some unforeseen circumstance. Two main types of restraint systems are stay rods and check rods.

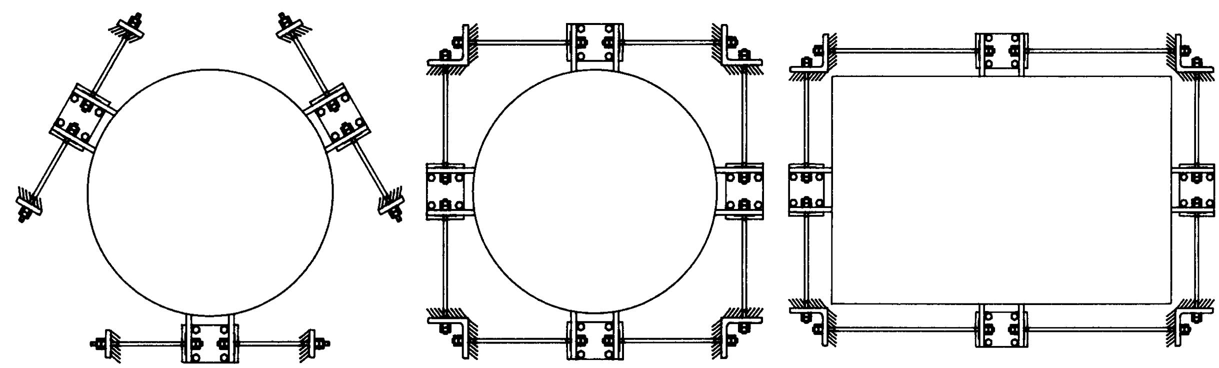


Figure 3-5

Stay Rods

Stay rods are used to rigidly restrain a vessel in the horizontal direction. These rods are installed horizontally in tension between a bracket on the vessel and a bracket attached to the vessel's support structure or foundation. Because of the negligible deflection of load cells under load, the stay rods will have little effect on the accuracy of the system when installed properly. It is necessary to install a number of rods to restrict a vessel fully in a horizontal plane; see Figure 3-5. On a circular vessel, the rods should always be tangential. This prevents the vessel from shifting in any direction, but leaves it free for thermal expansion/ contraction.

Figure 3-6 illustrates stay rods attached to a suspended vessel. The rods must be horizontal so that they do not affect the weighing accuracy. Fastening nuts are tightened so the rod is snug—do not overtighten. This placement of the nuts ensures the rods operate in tension and are never subjected to a compressive or buckling load.

Stay rods are used to:

- Improve system stability and accuracy by limiting vessel oscillation or vibration.
- Protect piping from fatigue due to constant vessel movement.
- Ensure the stability of tall slender vessels or vessels with heavy eccentrically-mounted equipment.
- Ensure the stability of vessels against wind, seismic forces or threat from vehicular traffic.
- Hold a vessel in place when mounted on canister cells. These cells have very little tolerance of side forces and must be loaded in the vertical direction only.

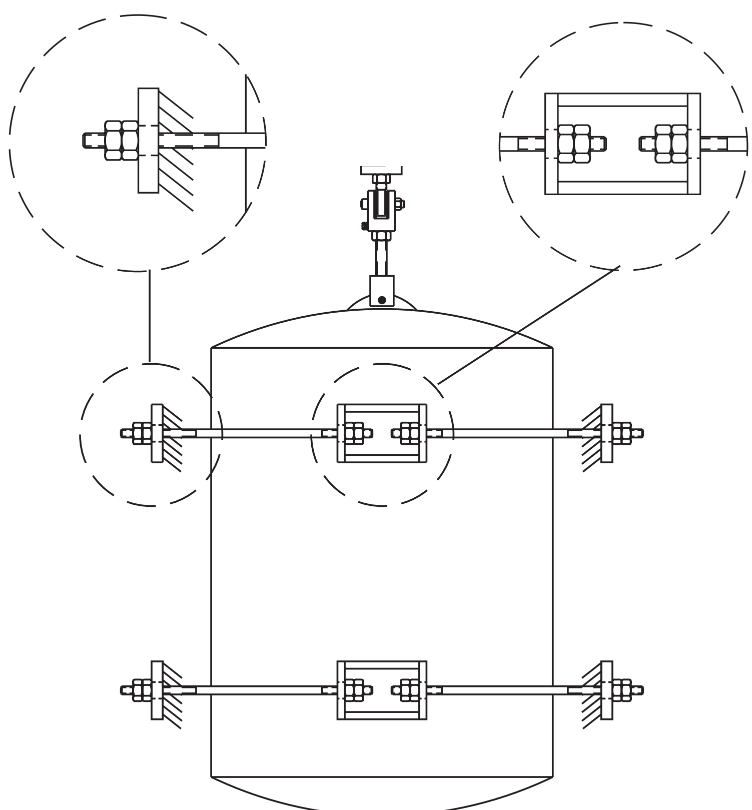


Figure 3-6

Caution When using stay rods to provide vessel stability, they are most effective when attached at or above the center of gravity of the filled vessel. Stay rods should be made as long as practical, as this will be beneficial in reducing forces in the vertical direction. It should be emphasized that the rods must be horizontal; for this reason one of the attachment points should be adjustable in a vertical direction.

Safety Check Rods

Safety check rods are similar to stay rods in that they may be applied to a vessel in similar fashion as stay rods. However, they are fitted loosely to the vessel and may also be applied in a vertical direction.

Safety check rods are left loose so that under normal operation they do not apply any axial forces to the weigh vessel. They are not an active part of the weigh system. The safety check rods shown do add to the tare weight of the vessel, but this is constant and does not affect the weighing accuracy. Safety check rods are, as the name implies, a safety feature intended to restrain the vessel if and when it is subjected to large external or internal forces or if there is a mechanical failure in the vessel's normal support mechanism.

Horizontal safety check rods should be used to:

- Assure the stability of tall slender vessels or vessels with heavy eccentrically-mounted equipment.
- Assure the stability of vessels against wind or seismic forces or threat from vehicular traffic.

As shown in Figure 3-7 (a), to be most effective, safety check rods must be fitted at or above the filled vessel's center of gravity. Note that stay rods will perform all these functions and more; however, safety check rods are less critical to system operation and therefore do not require the same attention to detail for successful installation.

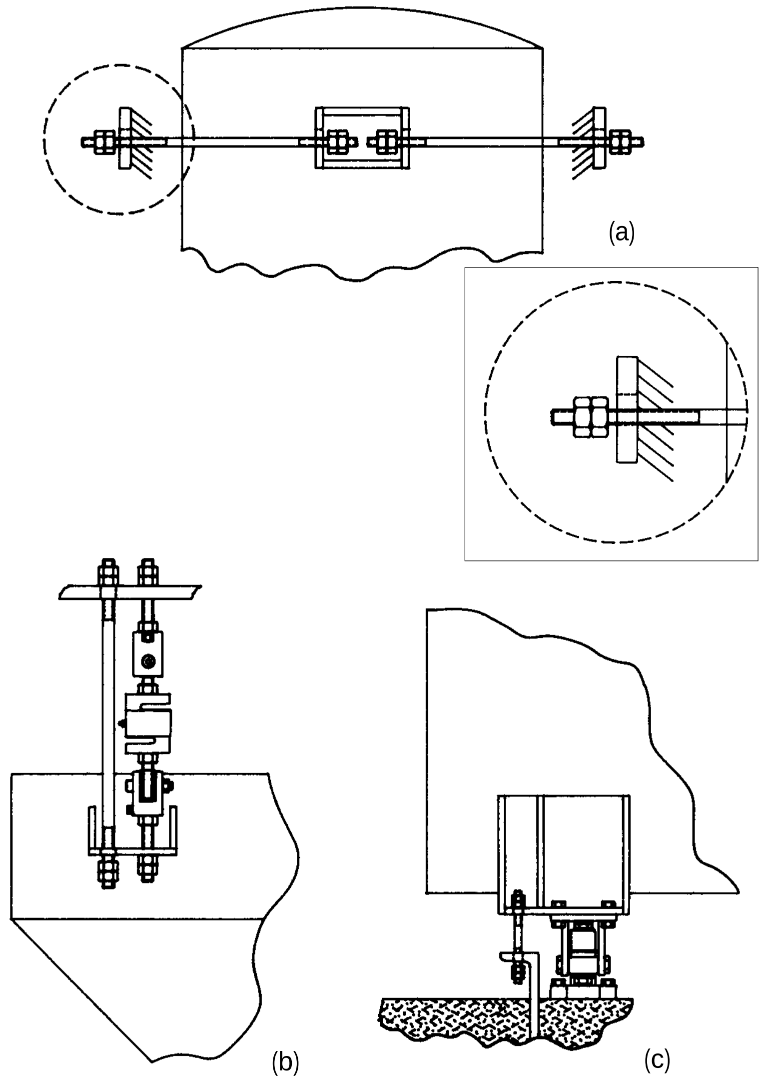


Figure 3-7

Vertical safety check rods should be used:

- On all vessels mounted in tension where failure of the normal suspension means would allow the vessel to fall and cause injury or damage, see Figure 3-7 (b).
- In place of horizontal check rods when it is not practical to use these to ensure the stability of tall slender vessels or those subjected to wind or seismic forces, see Figure 3-7 (c).

Vertical safety rods must be installed in an oversized hole in the lower bracket so that they do not interfere in any way with the vertical movement of the vessel.

For more information, see *Calculating Thermal Expansion of Vessels and Stay Rods* in Section 1.

Low-Accuracy Systems: Partial Mounting on Flexures

As noted earlier, low-accuracy weigh systems may be partially supported on flexures if the following conditions are met:

- The vessel contents are self-leveling.
- The vessel is symmetrical around a vertical line through the content's center of gravity.

These restrictions ensure that as the vessel fills, the center of gravity of the contents rises along a vertical line whose location is fixed relative to the support points. This ensures that each load cell always sees the same proportion of the load.

The horizontal cylindrical tank illustrated in Figure 3-8 is mounted on two flexures at one end and two load cells at the other.

It is very important that the vessel is level and the ends are identical in shape. This is a lower-cost weighing system which will work satisfactorily if low accuracy is acceptable.

Flexures may also be used with tension applications. Figure 3-9 is an example of a circular vessel suspended from one load cell and two flexures (or simply tension rods in this case).

Care must be taken to separate the flexures and load cells to opposite sides or ends of the vessel. In Figure 3-9, for example, the flexures could not be placed on one diagonal and the load cells on the other.

If these vessels are to be calibrated electrically, then the geometry of the vessel must be known accurately. This allows the percentage of the load carried by the load cell(s) to be calculated. A practical alternative is to calibrate with a known weight of liquid. It is not practical to calibrate these vessels with test weights since they could not be placed with any precision at the center of the vessel.

These arrangements should be avoided when the potential exists for weight to be transferred from one support to another. This can be caused by wind-loading, thermal expansion/contraction of pipes, etc.

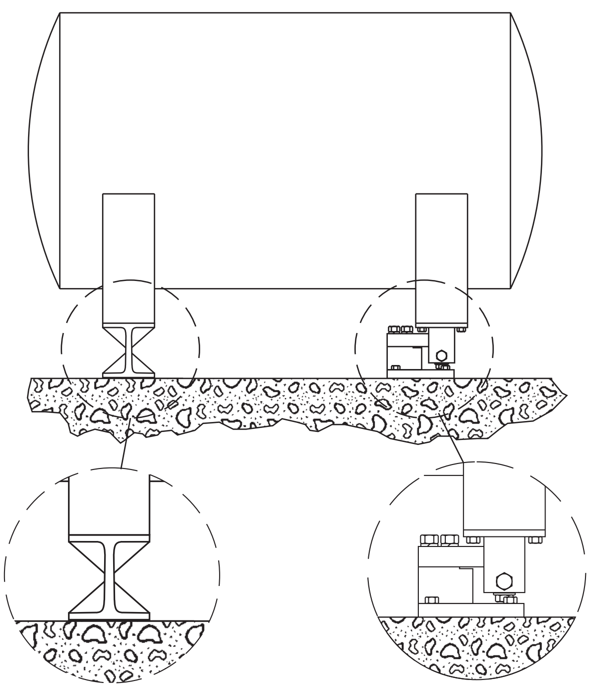


Figure 3-8

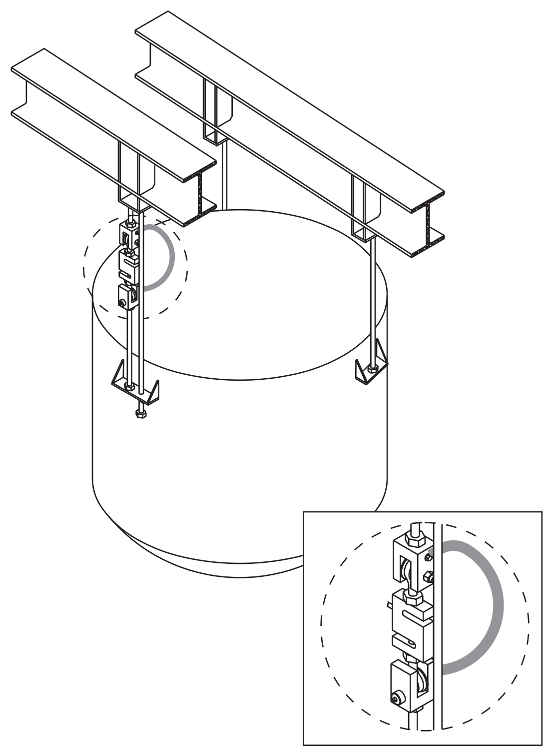


Figure 3-9

INSTALLATION & SERVICE TIPS

Before Installing

Here are some suggested practices we have learned from our years of experience in field installation of weighing devices. By sharing these installation tips, we hope to save you countless hours of service time and frustrations.

1. Inspect and Test

Always, always, inspect and test any component for your system before traveling to the job site. It is always easier to solve a problem or ask a question when you have the tools and time to approach the task before investing service and travel time.

2. Specifying Load Cells

When specifying load cells, be sure to use proper sizing techniques to determine capacity. To help you better understand sizing techniques, we have included an article on determining microvolts per graduation, which explains how to determine minimum readable signals and how to apply them.

3. Difference in Load Cell Construction

Understand that there are differences in load cell construction that determine their suitability for various applications. Stainless steel construction is preferred for wet or corrosive environments, but stainless steel alone is not always enough protection. Note that hermetic sealing is preferred over standard environmental protection for use in washdown environments.

4. Altering Load Cell Cable

Be careful not to cut or alter the load cell cable attached to the load cell. This affects the calibrated signal output and voids all manufacturer's warranties.

5. Retaining the Calibration Certificate

Always retain the calibration certificate supplied with each load cell. Put this in your customer or job file and use as a troubleshooting reference or replacement reference. On legal-for-trade scales where NTEP load cells are required, the end user is required to keep these certificates for inspection by the Weights and Measures inspector.

6. Service Situations

Approach all service calls prepared with a suitable ohmmeter, proper tools and replacement parts.

Determining Microvolts per Graduation

Whether sizing load cells for a mechanical conversion, replacing truck scale cells, or designing a weighing vessel, it's tempting to pick a grossly oversized load cell for "overload insurance." This practice can create a problem that can cost you many hours in troubleshooting and redesign. If you oversize capacity, you may cut your signal output to a point where your system will not operate as planned. Determining your application's required microvolts per graduation (µV/grad) will allow you to properly size a load cell, ensuring adequate signal and overload protection.

The signal sensitivity of electronic digital weight indicators is specified as a minimum microvolt per graduation value. A microvolt (µV) is one millionth of a volt. The µV per graduation value is the amount of scale output signal change required to change the meter display one graduation. If the scale output signal is below this value, the meter will not perform properly.

The following process will help you determine the µV per graduation rating of your weighing system:

1. Determine full scale output of the load cell (output signal at 100% of capacity).

   For example: A cell rated at 3.0mV/V, when supplied with 10V of excitation from a digital weight indicator, will provide 30 mV of full scale output.

   $$3.0\text{mV/V} \times 10\text{V} = 30\text{mV}.$$

2. Determine how much of the output will be caused by the <u>live load</u> in your application. If the cell has a capacity of 500 lb and the live load placed on it is 300 lb, then 60% of the total capacity of the cell is live load.

   $$\frac{300}{500} = .60 \text{ or } 60\%$$

3. Determine how much signal represents the live load by multiplying full scale load cell output by the actual amount of live load at full scale.

   $$30\text{mV} \times .6 = 18\text{ mV}$$

4. Actual µV/graduation rating is determined by dividing the live load signal by the number of graduations the electronic digital weight indicator is programmed to read. If the indicator is set for 5,000 graduations then:

   $$\frac{18\text{mV}}{5000\text{ grads}} = 3.6\ \mu\text{V/graduation}$$

If the µV/graduation rating was less than the minimum sensitivity rating on the indicator, the installation will not work. The live load signal needs to be increased. How can this be done?

- Increase the excitation level. In #1, if 15V of excitation were used instead of 10V, then 15 x 3.0mV/V = 45mV. By completing the rest of the formula, the µV/graduation would be 5.4 µV.
- Use a cell with higher full scale output. This works if the original cell was less than 3.0mV/V; generally no standard cells are available with more than 3.0mV/V output.
- Counterbalance the dead load off the load cell. This may allow the use of a smaller capacity load cell, thus raising the µV rating, as a greater portion of the total output will be live load signal.

> ⚠ **Caution** If you experience a signal problem, using an oversized load cell will worsen the µV/graduation rating. This is because even less of the full scale output would be live load signal. As an example, if a 1000 lb cell were in the above illustration instead of a 500 lb cell, only 30% of the capacity would be used. This would give a µV/graduation of $\frac{30\text{mV} \times 30\%}{5000 \text{ graduations}}$ = 1.8µV/graduation.

Load Cell Mounting Hardware Safety Guidelines

Install only load cell mounting hardware and assemblies that have been specifically designed for use in tank, hopper or hanging scale applications. Often, the use of an inferior-grade product results in component failure, which risks equipment damage and personal injury. These simple suggestions are provided to help minimize your exposure to vessel scale installation hazards.

1. Safety Backup

If failure of one or more load cell hardware assemblies could cause injury or damage, a safety backup (safety chains, safety rods, etc.) must be used. Also, the assemblies should be inspected routinely for damage, excessive wear or corrosion, and replaced if necessary.

2. Estimating Gross Load

To select the correct load cell or load cell hardware for a given application, it is necessary to know the total weight on the scale, including the net weight of product, the tare weight of the vessel, and the weight of the platform, tank or hopper, as appropriate.

3. Safe Load

Do not exceed the safe load figures listed in this catalog for any load cell hardware. Where shock loads are present, it may be necessary to derate these safe load figures depending on the severity of the shock load.

4. Load Distribution

In multiple load cell applications, make certain that the weight is evenly distributed between all cells.

5. Threaded Connections

Be sure that all threads of a threaded connection are in engagement. For example, an eye bolt that is screwed into an S-type load cell should protrude slightly on the opposite side.

6. Jam Nuts

Lock any threaded connections with a jam nut to prevent inadvertent disassembly. If a load is suspended from a single load cell, make sure the load cannot rotate, as this may loosen the jam nut.

7. Wire Rope Assemblies

With wire rope assemblies, do not twist the rope during assembly or disassembly. For example, do not remove a frozen nut from one end of a rope assembly by holding the opposite end.

8. Attachment Points of a Load Cell Hardware Assembly

Ensure that the attachment points of a load cell hardware assembly are aligned properly and that the assembly is essentially vertical.

9. Swaying in a Suspended Vessel Scale

If there is excessive swaying in a suspended vessel scale, apply horizontal checking to reduce the amplitude.

10. Hopper Scales: Guarding Against Contamination

With hopper scales, guard against contamination of the product being weighed as a result of the failure of the load cell or hardware assembly. For example, do not locate a wire rope assembly over a hopper scale where broken strands of wire could fall into the weighing vessel, contaminating the product being weighed.

11. Selecting Steel Rod or Any Other Weight-Bearing Components

Select steel rod or any other weight-bearing components so that their minimum tensile strength is at least four times the total weight carried by that component. Note that threaded rod is generally made from a low tensile strength mild steel which should be checked for tensile strength before use in any suspended vessel scale.

Load Cell Trimming

It may be necessary to trim the load cell outputs as a first step before starting the calibration process. Trimming is performed at the junction box to equalize the weight reading from all cells in a system. This ensures that the scale weighs correctly regardless of where the load is applied to the scale.

Trimming is necessary if:

1. It is a legal-for-trade weighing application.
2. The location of the center of gravity of the contents is not fixed, e.g., powder material which may accumulate on one side.
3. A high-accuracy weighing system is required.

Trimming is not necessary if:

1. Matched output load cells are used (as in the Paramounts).
2. Weighing self-leveling materials (liquids).
3. The vessel is partially supported on flexures.

2 and 3 above assume that the vessel's center of gravity rises along the same vertical line as the vessel is filled. Each load cell is always subjected to the same percentage of the weight.

Trimming involves placing the same weight over each load cell in turn, and adjusting the corresponding trim pot in the junction box until the indicator reads the same for all cells. To further illustrate load cell trimming, please review the following examples of signal trim and excitation trimming procedures.

Understanding Load Cell Trimming

Many weighing systems use multiple load cells and therefore require a summing junction box to tie or "sum" the load cell signals together, allowing a digital weight indicator to read a single "system" signal. The summing process actually wires multiple load cells so that all their signal lines and excitation lines are in parallel, providing instantaneous electronic summing of the signals.

Load cell summing is necessary because:

- Weight distribution in multiple load cell systems is not equal at each load cell. The vessel loading process, presence of agitators, and the characteristics of the material and many other factors affect weight distribution on the load cells.
- It is virtually impossible to make each load cell exactly alike. Load cell manufacturing process tolerances allow for some variance in individual cell specifications. This variance, if unchecked, would not allow for the kinds of accuracy required in modern process applications.

There are two summing methods; Excitation trim and Signal trim.

Excitation Trim

This is the oldest method of trimming the output from a strain gauge load cell. Excitation trimming adds series resistance to the excitation circuit of the load cell, thereby reducing the excitation voltage at the cell. The load cell with the lowest mV/V output receives the full excitation voltage. All other load cells in the system with a higher mV/V output receive proportionally smaller excitation voltages. This results in matched full load outputs for all load cells in the system.

Figure 1-1 is a functional diagram of an excitation trim J-box. Note that a variable resistor, or potentiometer (pot), is inserted in the + excitation lead of each load cell. If the pot is opened so that resistance is zero, the full excitation voltage is applied to the load cell. As resistance is increased, excitation voltage decreases.

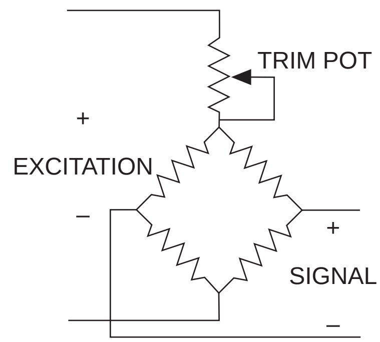


Figure 1-1: Excitation Trimming Load Cells

Excitation Trimming Procedure

The simplest method of trimming with excitation is to set up your system, turn all trim pots to the "open" or full excitation setting, and test each corner of the system with a calibrated test weight or any dead weight. Once the lowest output corner is located, the other cells are trimmed to match by physically loading with the same weights and adjusting the pots. This procedure can be practical if used in field replacement of load cells in light-capacity floor scales. It is not typically used in heavy-capacity scales where application of test weights to corners in such a manner is not practical.

Another method is "pretrimming." Here, the load cells are trimmed by mathematically calculating the excitation voltage for the load cell, then measuring the excitation voltage with a voltmeter, while adjusting the pot to the required voltage. The following five steps walk you through this procedure.

1. Determine how much excitation voltage your electronic digital weight indicator is supplying to the load cells. This is found by measuring, with a voltmeter, the actual excitation voltage present at the reference cell's excitation leads. For this example, we will use 10 volts DC.

   NOTE: The reference cell is the cell with the lowest mV/V rating, as shown on its calibration certificate.

2. Determine the exact mV/V rating of each load cell and locate the cell with the lowest rating. The exact mV/V rating is found on the calibration certificate supplied with each cell. Just because a cell is rated at 3 mV/V, don't assume it's exactly 3 mV/V.

   #1 = 2.997 mV/V #3 = 2.999 mV/V
   #2 = 3.003 mV/V #4 = 3.002 mV/V

   Cell number 1 has the lowest rating at 2.997 mV/V.

3. Calculate the trimming factory by multiplying the lowest mV/V by the excitation voltage.

   2.997 mV/V x 10V = 29.970 mV

4. Calculate the adjusted excitation voltage for the remaining load cells and adjust each respective trim pot to the appropriate voltage level.

   #1 = leave alone, lowest mV/V!
   #2 = 29.97 mV ÷ 3.003 mV/V = 9.980 volts
   #3 = 29.97 mV ÷ 2.999 mV/V = 9.993 volts
   #4 = 29.97 mV ÷ 3.002 mV/V = 9.983 volts

   The scale should now be trimmed.

5. Verify your results with certified test weights or a known amount of material.

Signal Trim

This form of trimming first appeared as an alternative to excitation trimming for indicators with gated power supplies. Because of the compatibility that signal trimming has with virtually all indicators and its relative immunity to temperature and vibration problems, signal trimming is gaining popularity for all installations. It involves adding a relatively high parallel resistance between the signal leads of each load cell as shown in Figure 1-2. The added parallel resistance creates a "leakage path" that shunts some of the available load cell signal away from the indicator. The larger this parallel resistance, the more signal available to the indicator from the load cell. Conversely, the smaller this parallel resistance, the less signal available to the indicator from the load cell.

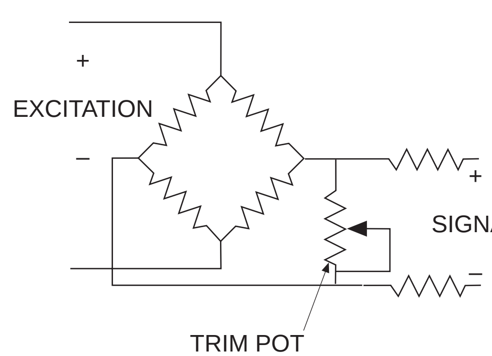


Figure 1-2: Signal Trimming Load Cells

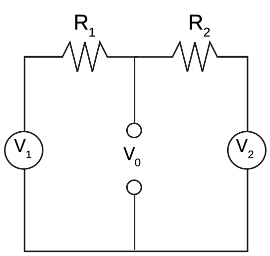
What is mV/V/Ohm Calibration?

The Paramounts Vessel Weighing System utilizes a unique system of mV/V/ohm calibration to ensure that all their load cell outputs match precisely. While there are other manufacturers who offer a similar calibration concept, there are important technical differences provided with Flintab products. To understand these differences, let's first review the "traditional" method of matching load cell outputs.

Traditional Approach

The conventional approach adjusts the short circuit current (mV/V/ohm) of each load cell to a standard value, within a close tolerance. This does, indeed, ensure that multiple load cell systems will be "corner adjusted" without further trimming, providing there are no mechanical load introduction asymmetries. It also ensures that the system corner adjustment is preserved, even when a load cell is subsequently replaced. It does not, however, preserve the system calibration. That will change!

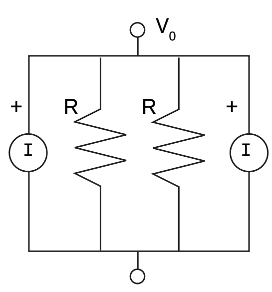
Let's look at this using a simple two-load cell example. Extension to the "n" load cell case is straightforward. In the figure below, two identical load cells are assumed and the conventional equations for



$$V_0 = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2}}{\frac{R_1+R_2}{R_1R_2}} \qquad V_1 = V_2 = V \qquad R_1 = R_2 = R$$

$$= \left[\frac{V_1}{R_1} + \frac{V_2}{R_2}\right] \times \left[\frac{R_1R_2}{R_1 + R_2}\right]$$

Where V_1 and V_2 are voltage sources, R_1 and R_2 are resistances. It is easier to understand the concepts by using the Norton equivalent circuit. Here, we have two current sources driving currents through the parallel combination of the load cell source impedances. The currents are the short circuit currents (I) of the respective load cell (mV/V/ohm) and they are set equal to some standard value. Note that the mV/V output is the same as in the arrangement above.



$$I = \frac{V}{R}$$

$$V_0 = \left[\frac{V}{R} + \frac{V}{R}\right] \times \left[\frac{RR}{R + R}\right] = V$$

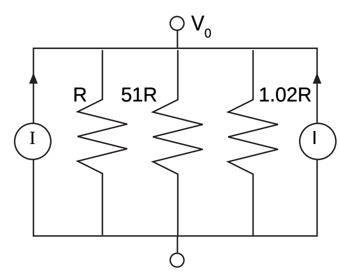
In either case, the system is "cornered." That is, the system output is the same whether the load cells are equally loaded or all the load is on one or the other load cell. Now let's replace the right hand load cell with a unit which has a source resistance that is 2% higher than the load cell it replaced. Since it must have the same short circuit current (mV/V/ohm), its open circuit output voltage will be set 2%

$$I = \frac{1.02\ V}{1.02\ R} = \frac{V}{R} \qquad V_0 = \left[\frac{V}{R} + \frac{V}{R}\right] \left[\frac{1.02\ RR}{2.02\ R}\right] = 1.01\ V$$

Now we have the two current generators driving their currents through the parallel combination of their source impedances as before. The system is still "cornered" but the system output is 1% higher, because the parallel combination of the two source impedances is now 1% higher, or the open circuit output voltage of the replacement load cell is 2% higher. So, the system must be recalibrated! As you know, this can be a difficult task, especially with high-capacity vessel scales. Unfortunately, the conventional approach does nothing to avoid the need for recalibration after load cell replacement.

Paramounts

Given the same set of circumstances regarding the replacement load cell (source impedance 2% higher), the short circuit current is set to the standard value, as before, but the **open circuit voltage is adjusted to a standard value** by loading the output terminals with resistance that drops the output voltage of the replacement load cell to the standard value. In this example, a resistance of 51R is placed across the output terminals of the replacement load cell and that additional resistor is shown added to the paralleled source resistances in the figure below.



$$V_0 = \left[\frac{V}{R} + \frac{V}{R}\right] \times \left[\frac{(1.02)\ (51)\ R^3}{(1.02)\ (51)\ R^2 + 1.02\ R^2 + 51\ R^2}\right] = \left[\frac{2\ V}{R}\right] \times \left[\frac{R}{2}\right] = V$$

Now the standardized current sources are driving their short circuit currents through the paralleled source resistances; the third resistance, the paralleled combination of the three resistances, is now equaling the original value of R/2. Hence the output voltage with the replacement load cell in place is the same as it was before the replacement. Not only is the system still "cornered," but the system calibration has been maintained. There is no need for system recalibration after load cell replacement. All Flintab SB4 and UB1 load cells are factory-calibrated in the above manner.

Load Cell Troubleshooting

Here are some easy-to-follow steps to help you troubleshoot potential load cell problems. Before you begin you will need a good quality digital multimeter, at least a 4 1/2 digit ohm meter. The tests are: physical inspection, zero balance, bridge resistance and resistance to ground.

Physical Inspection

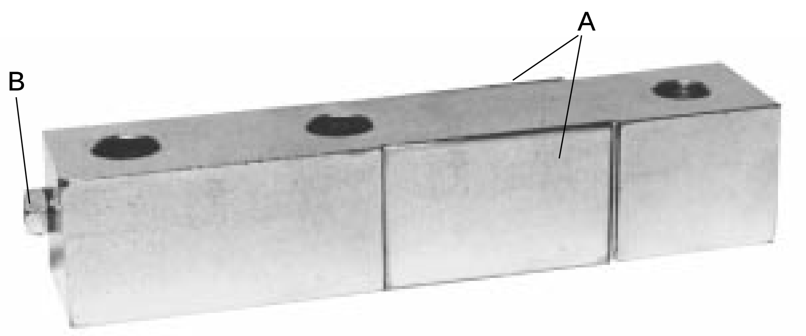
How does it look? If it is covered with rust, corroded or badly oxidized, chances are the corrosion has worked its way into the strain gauge area as well. If the general and physical condition appears good, then you need to look at specifics: sealing areas, the element itself, and the cable.

All areas of the load cell are sealed to protect the contents from contamination by water and chemicals. To see if any seals have been degraded, get right up close to the cell and look at the strain gauge seals (points A). Is rust concentrated on a part of the cover weld? If there is no cover, do you see any tiny holes in the potting? These are indications that there has been contamination to the gauge area. Check the load cell cable entrance (point B) for signs of contamination.

Other items to look for: metal distortion or cracks, metal rippling, cracks in the weld, or abrasions in the metal. It may be necessary to remove the load cell and check it for physical distortion against a straight edge.

No inspection would be complete without thoroughly inspecting the cable. Cable should be free of cuts, crimps and abrasions. If your cable is cut and in a wet environment, water or chemicals can "wick" up the cable into the strain gauge area, causing load cell failure.

If your physical inspection fails to uncover any identifiable damage, a more detailed evaluation is required.



Zero Balance

This test is effective in determining if the load cell has been subjected to a physical distortion, possibly caused by overload, shock load or metal fatigue. Before beginning the test, the load cell must be in a "no load" condition. That is, the cell should be removed from the scale or the dead load must be counterbalanced.

Now that the cell is not under any load, disconnect the signal leads and measure the voltage across the negative signal and positive signal. The color code for determining negative- and positive-signal leads is provided on the calibration certification with each load cell. The output should be within the manufacturer's specifications for zero balance, usually ± 1% of full scale output. During the test, the excitation leads should remain connected with the excitation voltage supplied by the digital weight indicator. Be certain to use exactly the same indicator that is used in the cell's daily operation to get a reading accurate to the application.

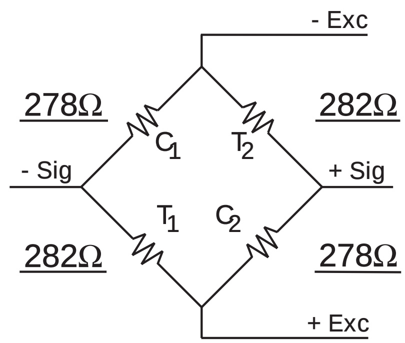
The usual value for a 1% shift in zero balance is 0.3mV, assuming 10 volts excitation on a 3 mV/V output load cell. To determine your application's zero shift, multiply the excitation volts supplied by your indicator by the mV/V rating of your load cell. When performing your field test, remember that load cells can shift up to 10% of full scale and still function correctly. If your test cell displays a shift under 10%, you may have another problem with your suspect cell, and further testing is required. If the test cell displays a shift greater than 10%, it has probably been physically distorted and should be replaced.

Bridge Resistance

Before testing bridge resistance, disconnect the load cell from the digital weight indicator. Find the positive and negative Excitation leads and measure across them with a multimeter to find the input resistance. Don't be alarmed if the reading exceeds the rated output for the load cell. It is not uncommon for readings as high as 375Ω for a 350Ω load cell. The difference is caused by compensating resistors built into the input lines to balance out differences caused by temperature or manufacturing imperfections. However, if the multimeter shows an input resistance greater than 110% of the stated output value (385Ω for a 350Ω cell or 770Ω for a 700Ω cell), the cell may have been damaged and should be inspected further. **

If the Excitation resistance check is within specs, test the output resistance across the positive and negative Signal leads. This is a more delicate reading, and you should get 350Ω ±1% (350Ω cell). Readings outside the 1% tolerance usually indicate a damaged cell.

Now comes the tricky part. Even if the overall output resistance test was within normal specifications, you could still have a damaged load cell. Often when a load cell is damaged by overload or shock load, opposite pairs of resistors will be deformed by the stress—equally, but in opposite directions. The only way to determine this is to test each individual leg of the bridge. The Wheatstone Bridge diagram, right, illustrates a load cell resistance bridge and shows the test procedure and results of a sample cell damaged in such a manner. We'll call the legs that are in tension under load T_1 and T_2, and the legs under compression C_1 and C_2.



With the multimeter, we tested each leg and got the following readings:

- T_1 (–Sig, +Exc) = 282Ω
- C_1 (–Sig, –Exc) = 278Ω
- T_2 (+Sig, –Exc) = 282Ω
- C_2 (+Sig, +Exc) = 278Ω

Note, when testing leg resistance, a reading of 0Ω or ∞ means a broken wire or loose connection within the cell.

In a good load cell in a "no load" condition, all legs need not have exactly equal resistance, but the following relationships must hold true:

1. $C_1=T_2$
2. $T_1=C_2$
3. $(C_1 + T_1) = (T_2 + C_2)$

In this damaged load cell, both tension legs read 4Ω higher than their corresponding compression legs. The equal damage mimics a balanced bridge in the output resistance test (3 above), but the individual leg tests (1, 2 above) show that the cell must be replaced.

****NOTE:** On multiple-cell applications for matched millivolt output, excitation resistance values may be higher than 110%.

Resistance to Ground

If the load cell has passed all tests so far but is still not performing to specifications, check for electrical leakage or shorts. Leakage is nearly always caused by water contamination within the load cell or cable, or by a damaged or cut cable. Electrical shorting caused by water is usually first detected in an indicator readout that is always unstable, as if the scale were constantly "in motion." The wrong cell in the wrong place is the leading cause of water contamination. Almost always, these leaking cells are "environmentally-protected" models designed for normal non-washdown, not the "hermetically-sealed" models that would have stood up to washdown and other tough applications.

Another cause is loose or broken solder connections. Loose or broken solder connections give an unstable readout only when the cell is bumped or moves enough so the loose wire contacts the load cell body. When the loaded scale is at rest, the reading is stable.

To really nail down electrical leakage problems though, test resistance to ground with a low-voltage megohm-meter. Use caution; a high-voltage meter that puts more than 50 VDC into the cell may damage the strain gauges. If the shield is tied to the case, twist all four leads together and test between them and the load cell metal body. If the shield is not tied to the case, twist all four leads and the shield wire together and test between them and the body. If the result is not over 5000 MΩ, current is leaking to the body somewhere.

If the cell fails this test, remove the shield wire and test with only the four live leads to the metal body. If this tests correctly (over 5000 MΩ), you can be reasonably sure current is not leaking through a break in the cable insulation or inside the gauge cavity.

Minor water infiltration problems can sometimes be solved outside the factory. If you are sure that water contamination has occurred and if you are sure that the cable entrance seal is the entry point, try this remedy: remove the cell to a warm, dry location for a few days, allowing the strain gauge potting to dry. Before putting the cell back into service, seal with silicone around the cable entry point in the load cell body. This prevents the reentry of water vapor into the cell.

Selecting Replacement Load Cells

Mechanical Conversions

In mechanical truck scale conversions, it is necessary to select a load cell that is large enough to carry the scale's *dead* load as well as the scale's *live* load while still providing adequate signal voltage. Dead load identifies the weight that is always present on the cell, such as the weight of the platform structure and the levers, transferred through the lever system. Live load describes the weight applied to the cell when weight or material is placed on the scale. In a conversion, the scale's live load comes through the existing mechanical lever system, so the multiple must be determined prior to sizing a cell.

Example: A mechanical truck scale has a 400 to 1 multiple and a scale capacity of 100,000 lb utilizing 20 lb graduations. To find the live load, we divide the scale's total capacity by its multiple:

$$\frac{\text{100,000 lb capacity}}{\text{400 multiple}} = \text{250 lb live load.}$$

To find the dead load at the steelyard rod, use a 1000 lb load cell and your standard indicator calibrated at 1000 lb x 1 lb. Install the load cell in the steelyard rod and power up the indicator. It will read your actual dead load. For this example let's assume the indicator displayed 200 lb.

Now we combine the live and dead loads to determine total load capacity.

	200 lb dead load capacity
+	250 lb live load capacity
	450 lb total load capacity

As load cells are not normally constructed at 450 lb capacity, we move up to the next highest increment, 500 lb. With a 500 lb capacity load cell we will be using about 50% of the cell for live load, providing us with plenty of live load signal output. Be careful not to simply overrate load cell capacity to ensure against overloads. In mechanical scale conversions, more cell capacity is often not better. See "Determining Microvolts Per Graduation" on page 4-3.

NOTE: To determine the dead load of a mechanical floor scale, use a small, hand-held tubular scale or a fish scale, and hook onto the transverse lever. Pull up until the weight of the of the empty scale is being read by the scale. This is the dead load at the load cell. Use the same formulas to determine live and dead loads for determining floor scale load cell size.

Electronic Replacements

In fully electronic truck, railroad track or tank scales, load cell sizing procedures are different. Here we are not using a multiple, as all of the dead load is resting on the load cells. For this example: 100,000 lb capacity truck scale with an 80,000 lb deck and 8-60,000 lb 3 mV/V canister load cells. The indicator will supply 10 VDC excitation and reads 100,000 lb by 20 lb.

1. Determine total scale capacity:

	80,000 lb = dead load capacity
+	100,000 lb = live load capacity
	180,000 lb total capacity needed

2. Determine load cell capacity:

	8 load cells
x	60,000 lb capacity
	480,000 lb total load cell capacity

In our example we have more than enough capacity to handle the live load, but we maybe in danger of reducing the live load signal too far by overrating the load cells. For further analysis, let's determine if we have enough signal voltage to properly operate our scale.

1. Divide live load by total load cell capacity:

   100,000 ÷ 480,000 = .208 or 20.8%

   This means only 20.8% of the total capacity will be used to measure live load.

2. Determine live load output of the load cells:

   3 mV/V (rated output) x 10 VDC excitation = 30 mV full scale

   Multiply 30 mV by the 20.8% live load usage:

   30 mV x .208 live load = 6.24 mV of full load signal

3. Determine scale graduation by dividing total capacity by readout increments. In this example we have a 100,000 lb scale reading by 20 lb increments, yielding 5000 graduations.

   100,000 lb capacity ÷ 20 lb = 5,000 graduations

4. Determine signal per graduation by dividing the total graduations by our full load signal:

   6.24 mV ÷ 5,000 graduations = 1.25 µV per graduation

1.25 µV (microvolts) is an extremely small signal and may be too small for your digital weight indicator to process accurately. Check your indicator specifications to determine if this signal is within specifications. For more information on determining microvolt per grad, see "Determining Microvolts Per Graduation."

NOTE: If it is a legal-for-trade application and NTEP load cells are required, there are several other considerations; consult the NTEP section for a detailed discussion, or consult your Rice Lake Weighing Systems Authorized Distributor.

Load Cell Wiring Guide

The following table shows the load cell wiring schemes used by several load cell manufacturers.

Manufacturer	Models	Excitation +	Excitation –	Signal +	Signal –	Shield	Sense +	Sense –
Advance Transducers		Red	Black	Green	White	Bare		
Allegany Technology		Green	Black	Red	White	Bare		
Artech		Red	Black	Green	White	Bare		
Beowulf		Green	Black	White	Red	Bare		
BLH	C2P1, C3P1, T2P1, T3P1	Green	Black	White	Red	Yellow		
Cardinal		Green	Black	White	Red	Bare		
Celtron	CSB, DSR, LOC, MBB, SQB, STC	Red	Black	Green	White	Bare		
	LPS	Red	Blue	Green	White	Bare		
	HOC, MOC	Green	Black	Red	White	Bare	Blue	Brown
Dillon	Canister Cell, Tension	Green	White	Black	Red	Orange		
	Compression	White	Green	Black	Red	Orange		
	Z-Cell	Red	Black	White	Green	Orange		
Electroscale		Red	Black	Green	White	Bare		
Flintec ((Flintab)	PC1, PC2, PC6, RC1, SB4, SB5, SB6, SB14, SLB, UB1, UB6	Green	Black	White	Red	Yellow		
Force Measurement		Red	Black	Green	White	Bare		
GSE		Red	Black	White	Green	Bare		
HBM	BLC, BLF, JRT, PWS, RSC, SBF, SB3, USB, U1T, Z6	Green	Black	White	Red	Yellow		
	BBS	Green	Black	White	Red	Bare		
	PLC	Red	Black	Green	White	Yellow		
Interface	SSM, 1200, 3200	Red	Black	Green	White	Bare		
Kubota		Red	White	Green	Blue	Yellow		
National		Green	Black	White	Red	Yellow		
NCI		Red	Black	White	Green	Bare		
Pennsylvania		Orange	Blue	Green	White	Bare		
Phillips		Red	Blue	Green	Gray	Bare		
Revere Transducers (Revere Corp. of America) (Transducers, Inc.)	62HU, 63HU, 363, 953, 9523	Red	Black	Green	White	Bare		
	92 CC, 93 CC, 42U, 43U, 263D, 462, 5102, 5103, 5123, 5223, 5723, 6762, 9102, 9103, 9123, 9363	Red	Black	Green	White	Orange		
	392B, 642, 652, 692B, BSP, HPS, USP1	Green	Black	White	Red	Bare		
	792, 933, SHB, SSB	Green	Black	White	Red	Clear		
	CP1, CSP1	Green	Black	White	Red	Orange		
	RLC	Pink	Grey	Brown	White	Bare		
Rice Lake Weighing Systems	RL20000, RL20000SS, RL20001, RL20001HE, RL30000, RL35023, RL35023S, RL35082, RL35083, RL39123, RL39523, RL50210, RL65044, RL70000, RL75016, RL75016SS, RL75040A, RL75058, RL75060, RL75223, RL90000, RLETB, RLETS, RLHSS, RLMK4	Red	Black	Green	White	Bare		
	RL50500, RL70000SS, RL71000HE, RL75016HE, RLMK15, RLMK21	Red	Black	Green	White	Orange		
	RLMK1	Red	Black	White	Green	Orange	Yellow	Blue
	RL1521	Red	Blue	Green	White	Bare		
	RL40BBS, RLBLC, RLSB2, RLSB2L, RLSB2M, RLSB250, RLSSB	Green	Black	White	Red	Bare		
	RL8C2P1SS, RLCSP1, RL75000SS	Green	Black	White	Red	Orange		
	RL1380, RL1385	Green	Black	White	Red	Yellow		
	RL1010, RL1040, RL1042, RL1140, RL1250, RL1260	Green	Black	Red	White	Bare	Blue	Brown
	RLHBB, RLHTO	Blue	Black	White	Red	Bare	Green	Grey
	RL32155	White	Blue	Green	Black	Orange	Yellow	Red
Sensotec		Red	Black	White	Green	Bare		
Sensortronics	60001, 60008, 60018, 60030, 60036, 60040, 60048, 60048SS, 60050, 60051, 60060, 60060-0101, 60063, 65007, 65016, 65016SS, 65016W, 65023, 65023S, 65023SS, 65024, 65040A, 65058, 65083, 65083S	Red	Black	Green	White	Bare		
	60007, 60064	Green	Black	White	Red	Bare		
	65088-1000, 65088-1114	Green	Black	White	Red	Orange		
Strainsert		Red	Black	Green	White	Bare		
Tedea Huntleigh	3411, 3421	Red	Black	Green	White	Bare	Blue	Brown
	240, 1010, 1022, 1040, 1042, 1140, 1250, 1260, 1320, 9010	Green	Black	Red	White	Bare	Blue	Brown
	355, 620, 3510	Blue	Black	White	Red	Bare	Green	Grey
Toledo		Green	Black	White	Red	Yellow		
Weightronix		Green	Black	White	Red	White/ Orange		

Calibration Guidelines for Vessel Weighing Systems

There are various methods available to calibrate a system. This section outlines some of the more common. However, the following recommendations apply regardless of the method adopted.

- If the scale is to be used in legal-for-trade weighing, check with the state or local Weights and Measures authority for specific requirements in your locality.
- The weight indicator should be switched on for 20 to 30 minutes (or as recommended by the manufacturer) before beginning calibration.
- The weighing system should be exercised several times by the application and removal of weight before beginning calibration. This ensures that everything is seated properly in place.
- While exercising the weighing system, check the return to zero each time the scale is unloaded. Be certain to turn off any Auto Zero function the indicator may have. If return to zero is poor, check for mechanical binding before proceeding.
- For best accuracy, use a weight of 80 to 100% of scale capacity for calibration.

Calibration Using Certified Test Weights

This method will yield the most accurate results—however, it can be difficult to place test weights in or on the vessel and attain accurate readings. These difficulties have been overcome in some installations by providing a means of hanging test weights from the vessel by chains.

1. Remove all weights from the vessel.
2. Zero the indicator (follow the manufacturer's instructions).
3. Place test weights on the vessel equal to 80 to 100% of scale capacity, evenly distributed.
4. Adjust the indicator until it reads the weight applied to the vessel.
5. Remove the test weights, check the return to zero, adjust if necessary.
6. Reapply the weights once more to verify the calibration.

NOTE: This method cannot be used with vessels partially mounted on flexures, since the weights cannot be placed accurately at the center of gravity of the contents.

Calibration Using Weighed Material

This method uses a known weight of material (often water or sand) as a test weight. This material is often loaded on a truck of known tare weight, weighed on a truck scale, and transported to the job site. It is important that material is not lost or altered in transit. Use the same calibration procedure as described under *Calibration Using Certified Test Weights* where the weighed material is used in place of the certified test weights.

Calibration Using Material Substitution Method

This method is used to accurately calibrate high-capacity scales when a limited amount of certified test weights is available. It allows you to substitute the known weight of material in a stepped fashion.

1. Remove all weight from the vessel.
2. Zero the digital weight indicator.
3. Place test weights on the vessel equal to at least 5% of scale capacity.
4. Adjust the indicator until it reads the weight applied to the vessel.
5. Remove the test weights and replace with material until the indicator accurately displays the weight of the certified test weights.
6. Again place the test weights on the vessel with the material. Record the indicator reading of the total weight of material and test weights.
7. Remove the test weights and replace with additional material until the indicator reads the total recorded weight.
8. Again place the test weights on the loaded vessel. Record the indicator reading.
9. Repeat this process until the applied weight (certified test weights and added material) is between 80 to 100% of total scale capacity.
10. The weight now applied to the scale is the weight of certified weights plus material multiple. (For example, if the certified weights total 5000 lb and 8 material substitutions were made, then the total weight on the scale is now = 5000 + (8 x 5000) = 45,000 lb)

NOTE: This method cannot be used with vessels partially mounted on flexures.

Calibration Using A Load Cell Simulator

This is perhaps the simplest and fastest method of scale calibration, particularly on large-capacity scales. It is less accurate than the other methods described. A major disadvantage is that it doesn't test the scale mechanically or take into account the influence of friction, piping, support deflection, etc. However, the method is sometimes sufficient for process weighing applications that need not meet legal-for-trade requirements.

To calibrate with a simulator:

1. Disconnect the cable from the junction box at the indicator.
2. Connect a load cell simulator to the indicator. The simulator should have a vernier for fine adjustments.
3. Set the simulator to 0.0 mV/V and zero the indicator.
4. Set the simulator's output (in mV/V) to simulate the output of the load cells at full scale capacity (ignoring dead load for now). To find the simulated full scale output, use the following formula:

   $$\frac{\text{Total Load Cell mV/V Output}}{\text{Total Load Cell Capacity}} = \frac{\text{Simulator mV/V Setting}}{\text{Displayed Weight}}$$

   For example:

   If four 5,000 lb 3 mV/V load cells are used for a 10,000 lb capacity scale, the simulator setting expected when 10,000 lb is placed on the scale can be determined by the following:

   $$\frac{\text{3.0 mV/V}}{\text{20,000 lb}} = \frac{\text{Simulator mV/V Setting}}{\text{10,000 lb}}$$

   Therefore, the simulator should be set to 1.5 mV/V.

5. Adjust the indicator to display the capacity of the scale (10,000 lb in our example) and set the indicator's span.
6. Adjust the simulator's output in steps (1.0 mV/V, 0.5 mV/V, 0.0 mV/V) and verify the indicator's linearity and return to zero.
7. Remove the simulator and reconnect the load cells. Recalibrate the indicator's zero point to take account of the actual dead weight of the vessel.
8. The accuracy of this method can be greatly increased by using a high-resolution 5 $^{1}/_{2}$ digit volt meter to measure the indicator's actual excitation voltage and to verify the actual mV output from the simulator. Those more accurate figures can then be used in the above procedure.

GLOSSARY

A

A/D (Analog to Digital)
Conversion of continuously varying (analog) voltage levels to discrete binary-numbered (digital) values (e.g., a load cell output can be fed through an A/D convertor to produce a continuous stream of digitized information and sent to a digital indicator).

ACCUMULATOR
A circuit or register device in a computer that receives, totals and stores numbers.

ACCURACY
Precision in the measurement of quantities and in the statement of physical characteristics. Accuracy is expressed in terms of error as a percentage of the specified value (e.g., 10 volts ± 1%), as a percentage of a range (e.g., 2% of full scale), or as parts (e.g., 100 parts per million).

AMBIENT CONDITIONS
The conditions (humidity, pressure, temperature, etc.) of the medium surrounding the load cell.

AMPERE
Unit of electrical current intensity. One ampere of current is 6.24×10^{18} electrons passing a point in one second; often shortened to “amp”.

ANALOG
Anything that corresponds, point for point or value for value, to an otherwise unrelated quantity; data represented by continuous values rather than in discrete steps.

ANGULAR LOAD, CONCENTRIC (Common Center)
A load applied concentric with the primary axis at the point of application, and at some angle with respect to the primary axis.

ANGULAR LOAD, ECCENTRIC (Off Center)
A load applied eccentric with the primary axis at the point of application and at some angle with respect to the primary axis.

APERTURE
The total range (in percentage) of full scale capacity over which a digital weight indicator’s “Automatic Zero Maintenance” (AZM) and “Push-button Auto Zero” (PAZ) functions will operate; Handbook 44 maximum is +2% of full scale.

APPROVED
Acceptable to the authority having jurisdiction over the area for in which a system or equipment will be used.

ASCII (American Standard Code for Information Interchange)
Pronounced “askee.” A seven-bit plus parity code established by the American National Standards Institute (ANSI) to achieve compatibility between data services.

ASSOCIATED APPARATUS
Apparatus in which the circuits are not necessarily intrinsically safe themselves, but may affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety. An associated apparatus has identified intrinsically safe connections for intrinsically safe apparatus and may also have connections for non-intrinsically safe apparatus.

ASYNCHRONOUS TRANSMISSION
Data transmission in which time intervals between transmitted characters may be of unequal length. Transmission is controlled by start bits at the beginning of each character and stop bits at the end of each character.

AUTHORITY HAVING JURISDICTION
Where public safety is primary, the “Authority Having Jurisdiction” may be a federal, state, local or other regional institution, department or individual. Some examples are a fire chief, fire marshal, chief of a fire protection bureau, labor department, health department, building official, electrical inspector or other having statutory authority. For insurance purposes, an insurance inspection department rating bureau or other insurance company representative may be the “Authority Having Jurisdiction”.

AIT (Auto Ignition Temperature)
The minimum temperature required for a substance to initiate or cause self-sustained combustion independently of the heating or heated equipment. Also referred to as ignition temperature.

AZM (Automatic Zero Maintenance)
An electronic means of providing “true zero” at all times on a digital scale. AZM compensates for such conditions as indicator or load cell drift or debris on a scale platform by electronically tracking out minor variations around zero; also called “zero tracking”.

AVERAGE PIECE WEIGHT (APW)
On a counting scale, the amount of weight divided by the number of samples which comprised that weight. APW is used by the counting scale to count pieces during normal operation.

AXIAL LOAD
A load applied along a line concentric with the primary axis.

B

BAUD
A unit of communications processing speed in digital data communications systems. The speed in baud is the number of discrete conditions of signal events per second. If each signal event represents only one bit condition, baud rate equals bits per second (BPS).

BCD (Binary Coded Decimal)
A data coding system in which four binary bits represent the decimal numbers 0 through 9. The BCD equivalent of the decimal number 187 is 0001 1000 0111.

BEAM
The indicating device of a lever scale.

BEZEL
A holder designed to receive and position the edges of a lens, meter, window or display.

BIDIRECTIONAL
Data flow in either direction on a wire between pieces of equipment. Each equipment item can both receive and transmit data.

BIT
The smallest unit of information in a binary system, consisting of a “0” or a “1” (formed from Binary Digit).

BLACKOUT
A sudden loss of AC line power usually as a result of an overload or other power failure.

BOARD OF GOVERNORS
National Conference on Weights and Measures body of officials that sets NTEP policy and has final say in disputes.

BRIDGE CIRCUIT
A network of four “leg” components connected so that the input signal may be applied across two branches in parallel and the output signal taken between two points, one on each side of the parallel branches. At some ratio of the resultant four arms of the circuit, the output points are at the same potential, and the output voltage is zero. The bridge then is said to be balanced or set to null.

BROWNOUT
A deliberate lowering of line voltage by a power company to reduce load demands.

C

CALIBRATION
The comparison of load cell outputs against standard test loads.

CALIBRATION CURVE
A record (graph) of the comparison of load cell outputs against standard test loads.

CANTILEVER BEAM
A beam-type load cell that has a machined-out center. The load sensing elements (strain gauges) are mounted on the inside perimeter of this machined center.

CAPACITANCE
The ability of a component or material to store an electrostatic charge; measured in farads. Because the farad is a very large quantity, capacitance in electronic applications is usually expressed in millionths of a farad (microfarads) or millionths of a millionth of a farad (pico farads).

CERMET
An alloy of ceramic and metal, usually titanium carbide and nickel, used as a resistance element in some variable resistors; acronym of ceramic metal.

CHECK RODS
Rods installed to prevent a vessel or other weighing system component from gross tipping or extended travel. They do not interfere with normal travel or expansion.

CHECKWEIGHER
A scale used to verify predetermined weight within prescribed limits.

CLASS III
Classes of scales used in commercial weighing not otherwise specified; grain test scales, retail precious metals and semiprecious gem weighing, animal scales, postal scales, and scales used to determine laundry charges.

CLASS IIIL
Vehicle, axle-load, livestock, railway track scales, crane and hopper (other than grain hopper) scales.

CLC (Concentrated Load Capacity)
Maximum load designated by the manufacturer that can be placed anywhere on the platform of a vehicle, axle-load or livestock scale using the prescribed test pattern (an area at least 4 feet long and as wide as the scale platform).

CMOS (Complementary Metal Oxide Semiconductor)
Chip technology characterized by a low power requirement and a high noise immunity. CMOS chips are susceptible to damage by electrostatic discharge (ESD).

CC (NTEP Certificate of Conformance)
Certification that a device meets all applicable requirements of Handbook 44.

COMBINED ERROR (Non-linearity and Hysteresis)
The maximum deviation from the straight line drawn between the original no-load and rated load outputs expressed as a percentage of the rated output and measured on both increasing and decreasing loads.

COMPENSATION
The utilization of supplementary devices, materials or processes to minimize known sources of error.

COMPRESSION
A force applied to a strain gauge that causes the gauge wires to compress and their cross-sectional area to increase, thus decreasing the gauge resistance.

CONFORMALLY COATED
Refers to load cells which have a protective coating applied over the strain gauges, terminal strip, etc., within the gauged cavity. The cavity opening may additionally be covered with side plates to protect against physical damage. These cells are suitable for normal indoor applications; they should not be used in wet or washdown applications.

CONTINUOUS MODE
Transmission of serial output data in which the data is transmitted automatically following each indicator display update; usually used to interface indicators to computers, score boards and other remote devices requiring constant data updating.

CONTROL DRAWING
A drawing or document provided by the manufacturer of the intrinsically safe or associated apparatus that details the allowed interconnections between the intrinsically safe and associated apparatus.

CPU (Central Processing Unit)
The computer module or chip that controls fetching, decoding and executing instructions; controls processing operations for the device.

CREEP
The change in load cell output occurring with time, while under load, and with all environmental conditions and other variables remaining constant; usually measured with Rated Load applied and expressed as a percent of Rated Output over a specific period of time.

CREEP RECOVERY
The change in no-load output occurring with time, after removal of a load which has been applied for a specific period of time; usually measured over a specified time period immediately following removal of rated load and expressed as a percent of rated output.

CURRENT
Flow of electrons past a point in a specified period of time; measured in amperes.

CURRENT LOOP
A current-based method of serial communications between digital devices; a logic high is represented by current flowing in the loop; a logic "low" is represented by a lack of current flowing in the loop.

D

d (Division)
Value of the smallest increment indicated (displayed) by a scale.

DASH POT
A dampening device used to reduce scale oscillations.

DEAD LOAD
The fixed force of the weigh bridge, platform, and other load-supporting structures of the scale, the value of which is to be permanently balanced or cancelled out in the weight or measuring system

DEFLECTION
The change in length along the Primary Axis of the load cell between no-load and Rated Load conditions.

DEMAND MODE
Transmission of serial output data which requires a manual "Print" command to initiate the output data. Usually used to interface indicators to printers.

DIGITAL
System of signal representation employing discrete rather than continuously variable (analog) values.

DIGITAL AVERAGING
The ability of a digital indicator to smooth bouncy or erratic readings by taking several readings and averaging them together before sending the signal to the display. Increasing the digital averaging slows the indicator's update rate.

DIP (Dual Inline Package)
An integrated circuit contained within a standard housing characterized by its low profile, rectangular body, and symmetrical placement of leads along two opposing sides of the device.

DORMANT SCALE
A built-in scale having a self-contained under structure.

DOT MATRIX
A method of printing in which a rectangular array (matrix) of spaces are filled in to form alphanumeric and punctuation characters.

DRIBBLE
In filling operations, the weight value over which material is slowly handled to provide a more accurate cutoff.

DROPOUT
A temporary loss of electrical power normally caused by utility and maintenance switching functions where break-before-make switching strategies are used.

E

e (Verification Scale Division)
Value of a verification scale division specified by the manufacturer; sets value for tolerances and accuracy class.

e_{min} (Minimum Verification Scale Divisions)
The minimum scale division or value for which a device complies with applicable requirements, e.g., bench or counter scale.

ECCENTRIC LOAD
Any load applied parallel to, but not concentric with, the Primary Axis.

EEPROM (Electrically Erasable Programmable Read Only Memory)
A data storage component whose data can be repeatedly read out; the stored data can be erased by an electrical signal and new data then can be programmed into the component.

ELECTRICAL NOISE
Extraneous undesirable currents or voltages which interfere with desirable electrical quantities. Some causes are distant lightning, radio transmitters, welding equipment, electrical switching equipment, poor brush contact on motors, and other electronic devices utilizing switching power supplies.

ELECTRON
A negatively-charged subatomic particle that orbits the nucleus of an atom. Electrical current is the flow of electrons.

ELECTROSTATIC CHARGE
An electric charge on the surface of an insulated object.

EMI (Electromagnetic Interference)
Interference caused by electrical fields due to capacitive coupling, or magnetic fields due to mutual inductance of electromagnetic fields (radio waves).

ENVIRONMENTALLY PROTECTED
Refers to load cells which have a strain gauge cavity filled with a potting compound. The cavity opening is also generally protected with loose-fitting side plates or molded plastic to protect against physical damage. These cells are protected from normal environmental factors in indoor or outdoor applications. They should not be submersed or washed down.

EPROM (Erasable Programmable Read Only Memory)
A data storage component whose data can be repeatedly read out; the stored data can be erased by applying ultraviolet light, and new data then can be programmed into the component.

ERROR
The algebraic difference between the indicated and true value of the load being measured.

ESD (Electrostatic Discharge)
A rapid discharge of an electrostatic potential that can cause damage to integrated circuits.

EXCITATION
The voltage or current applied to the input terminals of the load cell.

EXCITATION TRIM
Method of matching load cell outputs in a multicell system by adjusting the excitation voltage to each individual load cell. Adjustment is made by changing the setting of a variable resistor in series with the excitation input.

EXPLOSION PROOF ENCLOSURE
An enclosure that is capable of withstanding an explosion of a specified gas or vapor which may occur within it and of preventing the ignition of the gas surrounding the enclosure. The enclosure also must operate at such an external temperature so that it is incapable of igniting its surrounding atmosphere.

F

FACTORY MUTUAL (FM) SYSTEM APPROVED
All products displaying this symbol have been approved for use in hazardous (classified) locations when following the proper installation procedures and drawings, and utilizing intrinsic safety barriers.

FLEXURES
Thin steel or plastic bands or plates which replace the pivots and bearings of a conventional scale, allowing less movement and reducing friction.

FULCRUM
A pivot point for a lever.

FULL DUPLEX
Simultaneous, two-way, independent data transmission in both directions.

G

GATED POWER SUPPLY
A power supply that allows conduction only when signal magnitude is within specified limits.

GRADUATION
A mark on an instrument or vessel indicating degrees or quantity.

H

HALF DUPLEX
Data transmission in both directions, but not simultaneously (see Full Duplex).

HANDBOOK 44 (H-44)
A comprehensive set of requirements for weighing and measuring devices that are used in commerce and law enforcement activities; not a federal law, but developed and updated annually by the National Conference on Weights and Measures. Its complete title is "Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices."

HANDSHAKING
Exchange of predetermined signals between two devices for purpose of control.

HAZARDOUS (CLASSIFIED) LOCATION
A location where fire or explosion hazards may exist due to the presence of flammable gases or vapors, flammable liquids, combustible dust or easily-ignitable fibers or flyings.

HERMETICALLY SEALED
Refers to load cells which have a metallic protective cover welded or soldered in place to protect the strain gauge cavity. Some cells of this type have additional protection at the cable entry such as a glass-to-metal seal. These load cells provide the best possible protection in harsh chemical or washdown environments.

HIGH PASS FILTER
A filter passing frequency components above a designated frequency and rejecting components below that frequency.

HYSTERESIS
The maximum difference between load cell output readings for the same applied load. One reading is obtained by increasing the load from zero and the other reading is obtained by decreasing the load from rated load. Measurements should be taken as rapidly as possible to minimize creep.

I

INFLUENCE FACTORS
Environmental elements that may alter or interrupt an electronic or mechanical indication (e.g., temperature, humidity, radio frequency interference, barometric pressure, electric power).

INTERFACE
A device or circuit that allows two units to communicate. Some of the standard interfaces used in the scale industry are 20 mA current loop, BCD, RS-232, RS-422 and RS-485.

INTRINSICALLY SAFE CIRCUIT
A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions in its most easily ignitable concentration.

INTRINSICALLY SAFE SYSTEM
An assembly of interconnected intrinsically safe apparatus, associated apparatus and interconnecting cables in which the parts of the system, which may be used in hazardous (classified) locations, are intrinsically safe circuits; may include more than one intrinsically safe circuit.

INTRINSIC SAFETY BARRIER
A network designed to limit the energy (voltage and current) available to the protected circuit in the hazardous (classified) location under specified fault conditions.

INTRINSIC SAFETY GROUND BUS
A grounding system that has a dedicated conductor, separate from the power system, so ground currents will not normally flow, and which is reliably connected to a ground electrode in accordance with Article 200 of the NEC.

INSULATION RESISTANCE
The DC resistance measured between the load cell circuit and the load cell structure; normally measured at fifty volts DC and under standard test conditions.

INTERNATIONAL PROTECTION (IP) RATING
A rating system that defines a product's or enclosure's protection against the ingress of solid objects and liquids. See page 257 for a chart defining the IP rating system.

I/O (Input/Output)
The circuits or devices that allow a digital unit to send (output) data and receive (input) data.

J

J-BOX (Junction Box)
A box or enclosure used to join different runs of cable or wiring; it contains space and terminals for connecting and branching the enclosed conductors and adjustments to provide load cell trimming.

L

LATCH
To maintain a closed (energized) state in a pair of relay contacts after initial energization from a single electrical pulse.

LATCHING RELAY
A relay which locks into the mode for which it is energized (On or Off); requires a start-stop button; once activated it stays activated until the setpoint is reached or the stop button is pushed.

LED (Light Emitting Diode)
A semiconductor light source that emits visible light or invisible infrared radiation.

LEVER
A tool that transfers force equally with reduction or multiplication.

LIVE LOAD
The load applied to a scale base that is actually being measured by the weighing system.

LOAD
The weight or force applied to the load cell.

LOAD CELL
A device which produces an output signal proportional to the applied weight or force. Types of load cells include beam, S-beam, platform, compression and tension.

LOW PASS FILTER
A filter which passes frequency components below a designated frequency and rejecting components above that frequency.

M

MASS
The quantity of matter in a body.

MEGOHMMETER
A special ohmmeter for measuring resistances in the megohm (10^6 ohms) range; also called a megger.

METAL FILM RESISTOR
A fixed or variable resistor in which the resistance element is a thin or thick film of a metal alloy deposited on a substrate made of plastic or ceramic material.

MICRO
A prefix meaning millionths (10^{-6}); symbol is "µ".

MICROVOLTS PER GRADUATION
The number of microvolts of live load signal that are needed to change the display.

MINIMUM DEAD LOAD-Load Cells
Minimum dead load is specified for NTEP load cells. In a given application, the dead load applied to each cell must be greater than or equal to the minimum dead load specified by the load cell manufacturer.

MOTION DETECTION
A circuit used in an indicator to sense when the displayed weight data is changing at a greater rate than preset limits (or is unstable) and to inhibit certain functions during this time. Functions inhibited may be data output, entry of a push-button auto zero, entry of an auto tare value or activation of zero tracking.

MOV (Metal Oxide Varistor)
A voltage-dependent resistor whose resistance predictably changes with voltage applied; used in transient protectors as a shunt protection device.

N

n_{max} (Maximum Number of Scale Divisions)
The maximum number of scale divisions for which a product has been approved. The n_{max} must be greater than or equal to the number of divisions for which the scale will be configured.

NEGATIVE LOGIC
Binary logic in which a high negative state represents a "1" condition and a low negative state represents a "0" state.

NEMA
National Electrical Manufacturers Association.

NCWM (National Conference on Weights and Measures)
An association of state and local officials. Federal and industry representatives that adopt uniform (model) laws and regulations (e.g., NIST Handbook 44).

NIST (National Institute for Standards and Technology)
An agency of the federal government to which all precision measurements are traceable. Formerly the National Bureau of Standards (NBS)

NOMINAL LOAD CAPACITY
The designed normal maximum load cell capacity. Output load cell sensitivity is based on this capacity unless otherwise specified.

NON-LATCHING RELAYS
Relays that will stay at the logic level based on the current setpoint data. These relays will “toggle” from energized to de-energized states depending on the signal sent to them.

NON-LINEARITY
The maximum deviation of the calibration curve from a straight line drawn between the no-load and rated load outputs, expressed as a percentage of the rated output and measured on increasing load only.

NONVOLATILE MEMORY
A computer storage medium whose contents remain unaltered when the power is switched off; contents are available when power is switched on again.

NTEP (National Type Evaluation Program)
A program of cooperation between the National Conference On Weights & Measures, NIST, state weights and measures officials and the private sector for determining conformance of weighing equipment with the provisions of H-44.

O

OEM (Original Equipment Manufacturer)
A manufacturer who produces equipment for use or inclusion by another manufacturer in its product.

OHM
The unit of electrical resistance. The resistance through which a current of one ampere will flow when a voltage of one volt is applied.

OHM’S LAW
The relationship between current, voltage and resistance. Current varies directly with voltage, and inversely with resistance (I = E/R, where I = Current, E = Voltage and R = Resistance).

OUTPUT
The signal (voltage, current, pressure, etc.) produced by a load cell. Where the output is directly proportional to excitation, the signal must be expressed in terms such as Volts per Volt, Millivolts per Volt, or Volts per Ampere, etc., of excitation.

OUTPUT, Rated
The algebraic difference between the Outputs at no-load and at Rated Load.

OVERLOAD RATING, Safe
The maximum load, in percent of Rated Capacity, which can be applied without producing a permanent shift in performance characteristics beyond those specified.

OVERLOAD RATING, Ultimate
The maximum load, in percent of Rated Capacity, which can be applied without producing a structural failure.

OWM
Office of Weights and Measures at NIST.

OIML (International Organization of Legal Metrology)
Treaty organization that recommends technical requirements for weighing and measuring equipment prior to the sale or distribution of a model or type within the state, nation, etc.

P

PARALLEL CIRCUIT
A circuit in which the components are connected across each other. The voltage applied to each component is the same.

PARALLEL COMMUNICATIONS
Type of data communication in which all elements in an information item (bits in a word) are acted upon simultaneously, rather than one at a time as in serial communications.

PARITY
A method of error checking where an extra bit is sent to establish an even or odd number of ones in the data of a character.

PAZ (Push-button Auto Zero)
Extension of the AZM function of a digital weight indicator through the use of a front-panel push-button.

POISE
A moveable weight that counterbalances the load on a scale.

PORT
A point at which signals may be introduced to or extracted from a circuit, device, or system.

POTENTIOMETER
A variable resistor employed as a voltage divider.

POTTED CELL
A load cell which is environmentally sealed by filling the strain gauge cavity with a material that protects the gauges from environmental hazards such as moisture. The potting material must not interfere with normal strain gauge movement, and allow the gauges to return to their normal zero output position.

PREACT
Weight value which is set to allow for material in suspension during a filling operation.

PRESSURIZATION
The process of supplying an enclosure with clean air or an inert gas with or without continuous flow at sufficient pressure to prevent the entrance of combustible dust.

PRIMARY AXIS
The axis along which the load cell is designed to be loaded; normally its geometric center line.

PROTECTIVE COMPONENT
A component or assembly which is so unlikely to become defective in a manner that will lower the intrinsic safety of the circuit that it may be considered not subject to fault when analysis or tests for intrinsic safety are made.

PURGING
The process of supplying an enclosure with clean air or an inert gas at sufficient flow and positive pressure to reduce, to an acceptable safe level, the concentration of any flammable gases or vapors initially present, and to maintain this safe level by positive pressure with or without continuous flow.

R

RACEWAY
An enclosed channel designed for holding wires, cables, or busbars.

RAINPROOF
An enclosure so constructed, protected, or treated, as to prevent rain from interfering with the successful operation of the apparatus under specified test conditions.

RAINTIGHT
An enclosure so constructed or protected that exposure to a beating rain will not result in the entrance of water under specified test conditions.

RAM (Random Access Memory)
A data storage device that can be accessed in any order. It is known as a read/write memory, as information can be written into the memory, then read out when needed by the microprocessor. The contents of RAM are lost when the system is powered down.

REACTANCE
The opposition offered to the flow of alternating current by pure capacitance, pure inductance, or a combination of the two. Its unit is the “ohm”.

REFERENCE STANDARD
A force-measuring device whose characteristics are precisely known relative to a primary standard.

REMOTE SENSING
A method of regulating the excitation voltage to the load cells. Some indicators compensate for voltage drops occurring between the indicator and load cells by increasing the indicator excitation output voltage; other indicators compensate for this voltage drop by amplifying the load cell return signal.

REPEATABILITY
The maximum difference between load cell output readings for repeated loadings under identical loading and environmental conditions; the ability of an instrument, system, or method to give identical performance or results in successive instances.

RESISTANCE
Opposition to current flow offered by a purely resistive component; simple opposition to current flow. Measured in ohms. See REACTANCE.

RESISTIVITY
The electrical resistance offered by a unit cube of material to the flow of direct current between opposite faces of the cube. It is measured in "ohm-centimeters."

RESOLUTION
The smallest change in mechanical input which produces a detectable change in the output signal.

RFI (Radio Frequency Interference)
Radio frequency energy of sufficient magnitude to possibly affect operation of other electrical equipment.

ROM (Read Only Memory)
A memory unit in which instructions or data are permanently stored for use by the machine or for reference by the user. The stored information is read out non-destructively and no information can subsequently be written into the memory.

RS-232
A voltage-based serial method of data communication used to transfer data between digital devices. Two wires carry the data; one wire is signal ground, and several control wires may be used for handshaking. A logic "high" is from -3 to -25 volts and a logic "low" is from +3 to +25 volts. Transmission distance should be restricted to 50 feet.

S

SAFETY FACTOR
A figure denoting the overload (and allowance thereof) a device can withstand before breaking down.

SCALE
A device for weighing, comparing and determining weight or mass.

SENSITIVITY
The ratio of the change in output to the change in mechanical input.

SERIAL TRANSMISSION
A method of data transmission in which each bit of information is sent sequentially on a single channel.

SETPOINT
In a feedback control loop, the point which determines the desired value of the quantity being controlled.

SHEAR BEAM
A bending beam load cell in which the strain gauges are mounted on a thin web of material in a machined-out cavity in the load cell.

SHIFT TEST
A test intended to disclose the weighing performance of a scale under off-center loading.

SIDE LOAD
Any load acting 90° to the primary axis at the point of axial load applications.

SIGNAL TRIM
A method of matching load cell outputs in a multicell system by adjusting the output signal voltage through a variable resistor placed across the signal leads.

SIP (Signal In-Line Package)
A flat, molded component package having terminal lugs along one side; half of a dual in-line package (DIP).

SPAN
The difference between the highest value and the lowest value.

STABILIZATION PERIOD
The time required to ensure that any further change in the parameter being measured is tolerable.

STACK
A temporary storage area in a computer memory consisting of a small group of registers. Data stored in the stack is retrieved from the stack in reverse order in which it is stored.

STANDARD TEST CONDITIONS
The environmental conditions under which measurements should be made, when measurements under any other conditions may result in disagreement between various observers at different times and places. The conditions are as follows: Temperature: 72° ± 3.6°F (23° ± 2°C) Barometric Pressure: 28 to 32 inches Hg.

STATIC OVERLOAD CAPACITY
Capacity as a percentage of nominal load limit capacity, in which the load cell can safely be loaded to this limit with no adverse affect on the performance or any change in its zero balance or other specifications.

STAY RODS
Rods installed to rigidly restrain a vessel or other weighing system component in the horizontal position. They will have little effect on the accuracy of the system when installed properly.

STRAIN GAUGE
A device for detecting the strain that a certain force produces on a body. The gauge consists of one or more fine wires cemented to the surface under test. As the surface becomes strained, the wires stretch or compress, changing their resistance. Several strain gauges are used to make up a load cell.

T

TARE
The weight of an empty container or vehicle, or the allowance or deduction from gross weight made on account thereof.

TEMPERATURE COEFFICIENT
A figure which states the extent to which a quantity drifts under the influence of temperature.

TEMPERATURE EFFECT, On Rated Output
The change in rated output due to a change in ambient temperature. Usually expressed as the percentage change in rated output per 100°F change in ambient temperature.

TEMPERATURE EFFECT, On Zero Balance
The change in zero balance due to a change in ambient temperature. Usually expressed as the change in zero balance in percent of rated output per 100°F change in ambient temperature.

TEMPERATURE RANGE, Compensated
The range of temperatures over which the load cell is compensated to maintain rated output and zero balance within specific limits.

TEMPERATURE RANGE, Safe
The extremes of temperatures within which the load cell will operate without permanent adverse change to any of its performance characteristics.

TERMINAL RESISTANCE, Corner to Corner
The resistance of the load cell circuit measured at specific adjacent bridge terminals at standard temperature with no load applied and with the excitation and output terminals open-circuited.

TERMINAL RESISTANCE, Input (Excitation)
The resistance of the load cell circuit measured at the excitation terminals at standard temperature with no load applied and with the output (signal) terminals open-circuited.

TERMINAL RESISTANCE, Output (Signal)
The resistance of the load cell circuit measured at the output signal terminals at standard temperature with no load applied and with the excitation terminals open-circuited.

TOLERANCE
The amount of error that is allowed in a value. It is usually expressed as a percent of nominal value, plus or minus so many units of measurement.

TRACEABILITY
The step-by-step transfer process by which the load cell calibration can be related to primary standards.

TRANSDUCER
A device that converts energy from one form to another.

TRANSIENT
A momentary surge on a signal or power line. It may produce false signals or triggering impulses and cause insulation or component breakdowns and failures.

TRIAC
A three-terminal, gate controlled, bidirectional silicon switching device that can switch either alternating or direct currents.

TRIM
To make a fine adjustment, as of load cell outputs in a multicell system.

V

v_{min} (Minimum Verification Scale Division/Load Cell)
A parameter used to select load cells for NTEP approved applications. For single cell applications, v_{min} must be less than or equal to the scale division size; for mechanical scale conversions using one load cell, v_{min} must be less than or equal to the scale division size divided by the scale multiple. For a scale using more than one load cell, v_{min} must be less than or equal to the scale division divided by the square root of the number of cells.

VOLATILE MEMORY
A computer storage medium whose contents are lost when there is a loss of power.

VOLT
The unit of voltage, potential difference and electromotive force. One volt will send a current of one ampere through a resistance of one ohm.

VOLTAGE
The electrical potential difference that exists between two points and is capable of producing a flow of current when a closed circuit is connected between the two points.

VOLTAGE DIP
A temporary decrease in voltage level lasting at least one alternating current cycle.

VOLTAGE SPIKE
Large damaging voltage pulse caused when lightning strikes a power line, communication line, a signal or sensing line, or even the ground nearby.

VOLTAGE SURGE
A temporary rise in voltage level lasting at least one alternating current cycle.

W

WATER-PIPE GROUND
An earth connection made by running a strong wire to the nearest cold water pipe.

WATER TIGHT
An enclosure so constructed that moisture will not enter the enclosure under specified test conditions.

WEATHER PROOF
An enclosure so constructed or protected that exposure to the weather will not interfere with successful operation of its contained equipment.

WEIGHT
The force or amount of gravitational pull by which an object or body is attracted toward the center of the earth.

Z

ZENER DIODE
A semiconductor diode which is used in the reverse biased condition. It exhibits a nondestructive breakdown at a predetermined reverse voltage, so while the diode is operating in this breakdown region, an increase in current flow through the diode will not result in increased voltage drop across the diode. It is used in voltage regulation circuits and as a voltage limiting device in intrinsic safety barriers.

ZERO BALANCE
The output signal of the load cell with rated Excitation and with no load applied, usually expressed in percent of Rated Output.

ZERO RETURN
The difference in Zero Balance measured immediately before Rated Load application of specified duration, measured after removal of the load, and when the output has stabilized.

ZERO SHIFT, Permanent
A permanent change in no-load output.

ZERO STABILITY
The degree to which the load cell maintains its Zero Balance with all environmental conditions and other variables remaining constant.