LOAD CELL AND WEIGH MODULE HANDBOOK

A Comprehensive Guide to Load Cell Theory, Construction and Installation

RICE LAKE
WEIGHING SYSTEMS

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on load cells and weigh modules

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1.0 Load Cell Types

Load cells are built in various sizes and types for various applications. We will look at the different type of load cells.

1.1 Canister

The canister cell is the earliest load cell design. It is either hermetically sealed or welded to protect the gauges.
See Figure 1-1 Canister Load Cell.

Canister cell popularity is waning as their cost is 2 or 3 times that of a bending beam cell. There are two types of canister construction, single column and multiple column. Single-column canisters cannot normally withstand a side load of over 15%. Multiple column canister cells withstand more side load than the single-column variety. The canister cell ranges in size from 100lbs up to 500,000lbs. The normal safe overload is 150% of full scale (F.S.) but some models are able to withstand a 300% F.S. overload. There is no means through visual inspection or labeling to identify which cells are singular or multiple column. **Refer to original manufacturer's specifications or Rice Lake Weighing Systems' Load Cell Guide to determine your cell's specifications.**

Canister cells are made of high alloy tool steel with an epoxy finish, or stainless steel. Their rated excitation ranges from 10VDC to 20VAC/DC. Common bridge resistances are 350Ω and 480Ω.

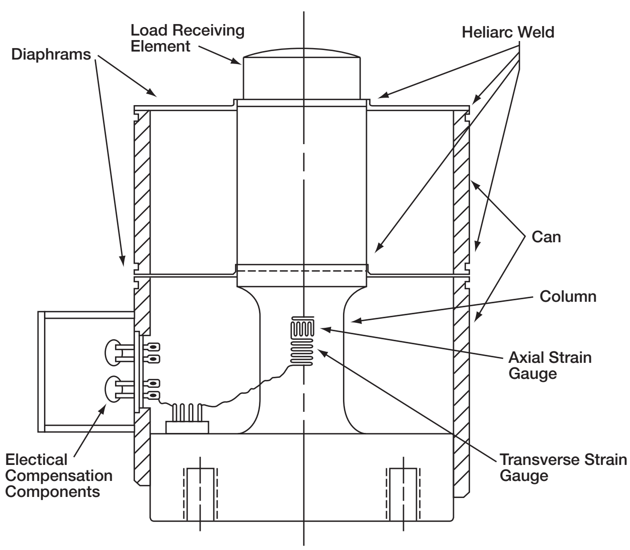


Figure 1-1. Canister Load Cell

1.2 Single-Ended Beam

The single-ended shear beam cell is designed for low-profile scale and process applications. The shear-beam cell strain gauge cavity contains a thin metal diaphragm onto which the strain gauges are mounted. Typical shear beam capacities range from 1,000lbs through 20,000lbs, although some manufacturers offer shear beams up to 40,000lbs. One end of the shear-beam contains the mounting holes while the opposite end is where the cell is loaded. The cell should be mounted on a flat, smooth surface with high strength hardened bolts. The larger shear beam cells have more than two mounting holes to accommodate extra bolts and keep the hardware from stretching under stress load. See Figure 1-2 Single-Ended Shear Beam.

Shear beams operate best in a temperature range of +15°F to 115°F. Their maximum safe operating range with minimum performance change is from 0°F to 150°F. Shear-beam zero outputs should be frequently checked when operating at high temperatures. These cells may be overloaded statically up to 150% of rated load without damage. Overloads in excess of the safe overload rating may permanently affect the accuracy and performance of the cell. Shock loads having peak values in excess of 120% of rated cell capacity may also affect the calibration and should be avoided.

Shear beams may be constructed of tool steel, or stainless steel for use in harsh environments. Just because a cell is made of stainless steel does not mean it can be used in washdown environments. Appropriate sealing is also important.

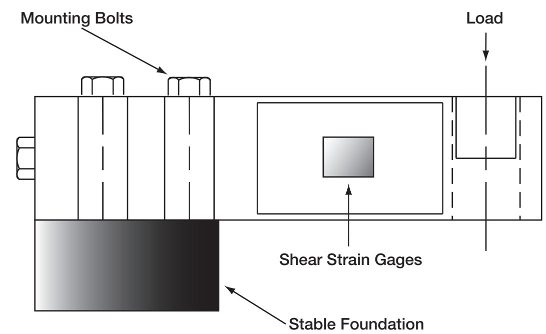


Figure 1-2. Single-Ended Shear Beam

1.3 Double-Ended Beam

The double ended shear beam characteristics are similar to those of the single-ended shear beam. The most common bridge resistance for this load cell is 700Ω. It is most commonly used in truck scales and tank and hopper applications. Instead of being secured at one end with the load applied to the other end as in the single-ended shear beam, the double-ended shear beam is secured at both ends with the load applied to the center of the load cell. As in all shear beam designs the strain gauges are mounted on a thin web in the center of the cell's machined cavity. See Figure 1-3 Double Ended Shear Beam.

1.4 Cantilever Beam

Cantilever beams are similar to shear beams. However, the cantilever beam does not have a thin web located in the strain gauge cavity. The cantilever beam is machined all the way through. The strain gauges are mounted along the inner edges of the cavity. Most cantilever beams have a bridge resistance of 350Ω and either 3mV/V or 2mV/V full scale outputs. They range from capacities of 25lb up to 10,000lbs. However, there may be a few larger cantilever beams being used. They can be used in tension or compression applications.

1.5 S-Beam

S-Beam load cells derive their name from their shape which, of course, is the shape of the letter S. The S-beam is normally used in tension applications. However, there are S-beams available which are bidirectional. They are primarily used for mechanical-to-electronic scale conversions, platform scale and general purpose weighing applications. They vary in size from as low as 25lbs to as high as 20,000lbs. When mounting an S-beam, remember to include the side from which the cable extends is the dead portion of the system. Movement of the cable in the live part of the system can be a source of weighing errors.

1.6 Platform

The platform load cell is sometimes called a dual-guided cantilever beam cell but is more commonly referred to as a single point cell. They are used in light capacity bench scales. They are most commonly made out of aluminum. Some platform scales have built-in overload stops. Safe overloading of 150% full scale is permissible at the center loading point on some platform load cells. They are commonly made in 2kg through 1000kg and 2lbs through 1000lb sizes. The bridge resistance is commonly 350Ω. See Figure 1-4 Platform Load Cell.

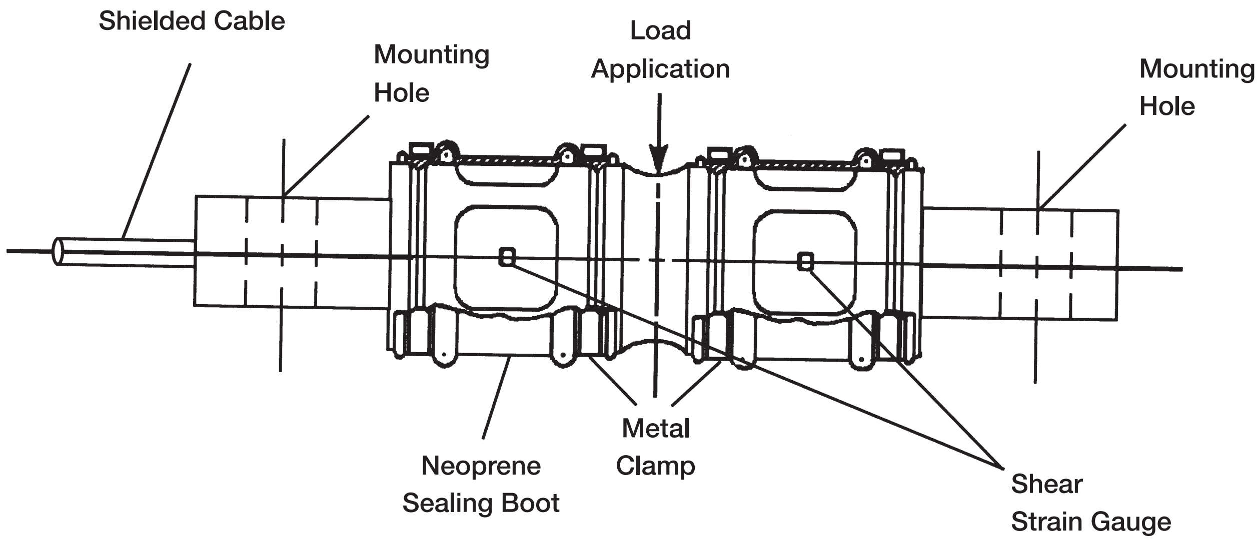


Figure 1-3. Double-Ended Shear Beam

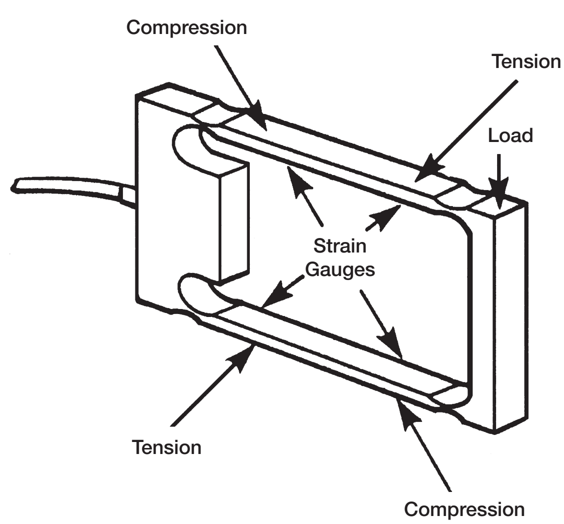


Figure 1-4. Platform Load Cell

2.0 Load Cell Construction

2.1 Materials

Aluminum Load Cells

Aluminum load cell elements are used primarily in single point, low capacity applications. The alloy of choice is 2023 because of its low creep and hysteresis characteristics. Aluminum load cells have relatively thick web sections compared to tool steel cells of comparable capacities. This is necessary to provide the proper amount of deflection in the element at capacity. Machining costs are usually lower on aluminum elements due to the softness of the material. Single point designs can be gauged for costs similar to those of bending beams.

Tool Steel Load Cells

Load cells manufactured from tool steel elements are by far the most popular cells in use today. The cost to performance ratio is better for tool steel elements compared to either aluminum or stainless steel designs. The most popular alloy are 4330 or 4340 because they have low creep and low hysteresis characteristics. This type of steel can be manufactured to spec consistently, which means that minute load cell design changes don't have to be made every time a new lot or new steel vendor is selected.

Stainless Steel Load Cells

Stainless steel load cells are made from 17-4ph, which is the alloy having the best overall performance qualities of any of the stainless derivatives. Stainless steel cells are more expensive than tool steel load cells. They are sometimes fitted with hermetically sealed web cavities which makes them an ideal choice for corrosive, high moisture applications. Stainless steel load cells that are not hermetically sealed have little advantage over comparable cells constructed of tool steel, other than a higher resistance to corrosion.

3.0 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 (Ingress 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.

3.1 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. 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.

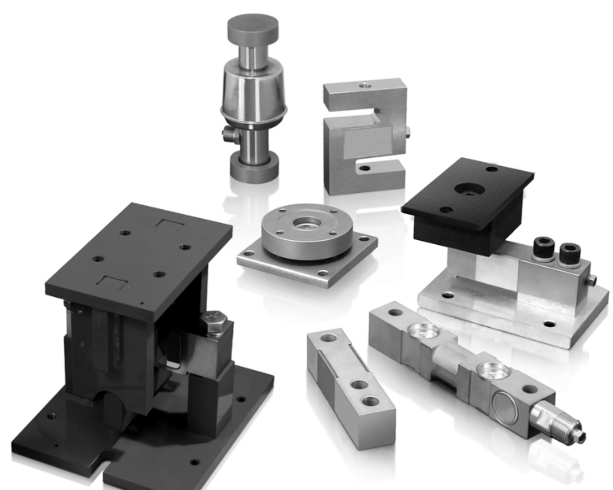
Although environmentally protected load cells keep out unwanted contaminants, they are not suited for high moisture, steam, or direct washdown applications. The only long-term strategy for these applications is to use true hermetically sealed load cells.

3.2 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.



3.3 Ingress 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 Ingress Protection (IP) rating system. We find the IP numbers and their definitions are suitable for the classification of hermetically sealed and environmentally 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
IP65	Dust proof, protected from splashes and low-pressure jets
IP66	Dust proof, protected from strong water jets
IP67	Dust proof, protected from temporary immersion in water 1 meter deep for 30 minutes
IP68	Dust proof, protected from continuous immersion in water under more severe conditions than IP67
IP66/68	Dust proof, protected from strong water jets and/or constant immersion
IP69K	Dust tight and withstands high-pressure, high-temperature water

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.

4.0 Selecting the Number of Supports and Load Cell Capacity

4.1 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 Section 22.0 on page 47.

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.

4.2 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:
  - Is your dead weight accurate?
  - Will the load be evenly distributed on all cells?
  - Is the vessel fitted with an agitator or subjected to shock loading?
  - Is it possible the vessel will be overfilled, exceeding your live weight value?
  - Will the vessel be subjected to wind or seismic loading? For more information, see Section 22.0 on page 47.

A good rule of thumb is to select a load cell with a capacity 25-50% 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 7.0 on page 11 for information on how to determine this 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.

5.0 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.

5.1 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.

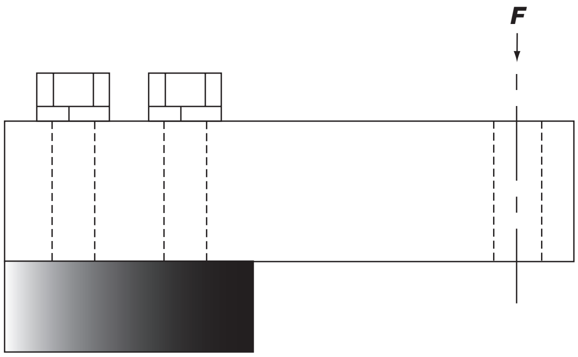


Figure 5-1.

Figure 5-1 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.

5.2 Angular Loading

This is a condition where the load F is introduced through the loading hole, but at an angle to its center line (see Figure 5-2). 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.

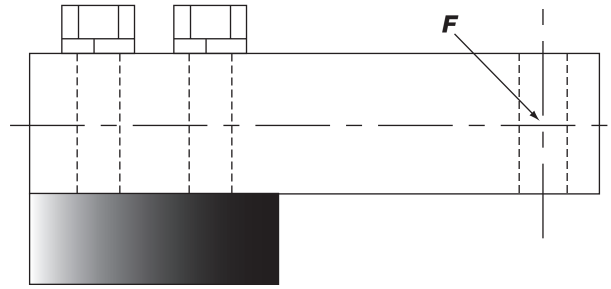


Figure 5-2.

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.

5.3 Eccentric Loading

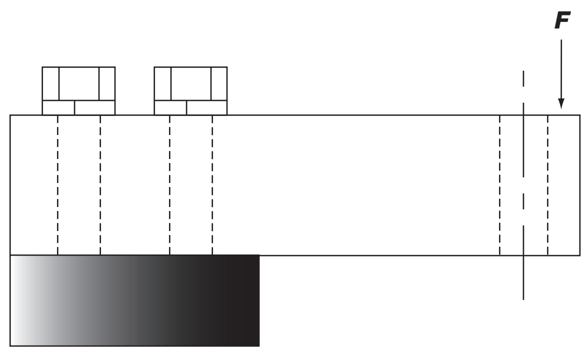


Figure 5-3.

This is a condition where the load F is applied vertically to the cell, but its line of action is shifted away from the vertical line through the loading hole (see Figure 5-3). 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.

5.4 Side Loading

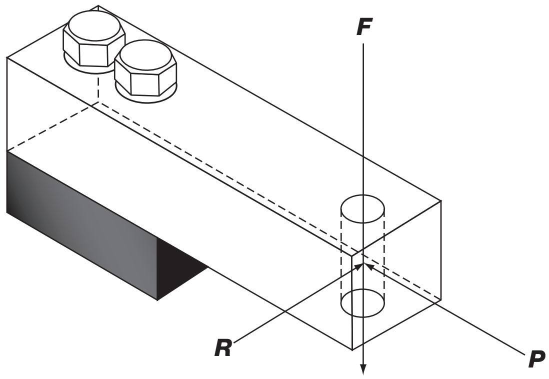


Figure 5-4.

This is a condition where the vertical load F (which you are trying to measure) is accompanied by a side force R applied at 90° to F (see Figure 5-4). 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 typically the result of thermal expansion/contraction, mounts which are not level, and vessel dynamics (caused by mixers, etc.).

5.5 Twisting Loads

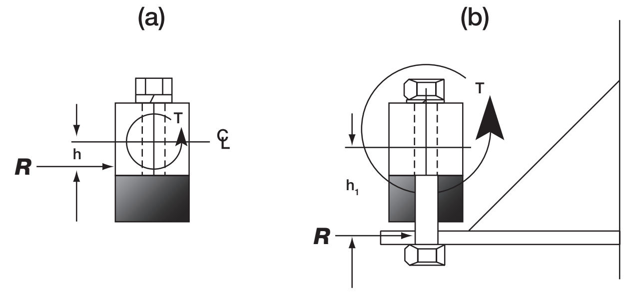


Figure 5-5.

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 5-5(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 5-5(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 h1 to the neutral axis.

Figure 5-6 illustrates a torque of magnitude Fy exerted as the result of the load F being applied at a distance y from the loading hole center line.

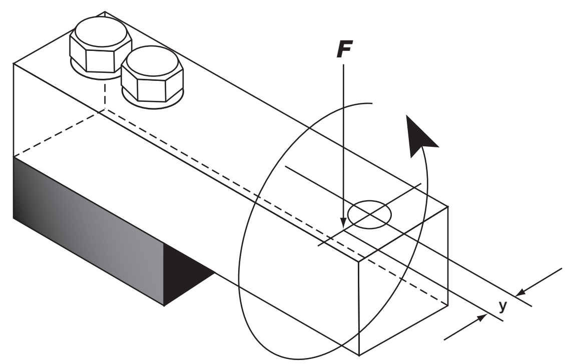


Figure 5-6.

Mounts which are out of level as well as 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.

6.0 Load Cell Electrical Theory

6.1 Wiring

A load cell may have a cable with four or six wires. A six-wire load cell, besides having + and - signal and + and - excitation lines, also has + and - sense lines. These sense lines are connected to the sense connections of the indicator. These lines tell the indicator what the actual voltage is at the load cell. Sometimes there is a voltage drop between the indicator and load cell. The sense lines feed information back to the indicator. The indicator either adjusts its voltage to make up for the loss of voltage, or amplifies the return signal to compensate for the loss of power to the cell.

Load cell wires are color coded to help with proper connections. The load cell calibration data sheet for each load cell contains the color code information for that cell. Rice Lake Weighing Systems also provides a load cell wiring color guide on the back cover of our Load Cell Guide.

6.2 Calibration Data

Most load cells are furnished with a calibration data sheet or calibration certificate. This sheet gives you pertinent data about your load cell. The data sheet is matched to the load cell by model number, serial number and capacity. Other information found on a typical calibration data sheet is output expressed in mV/V, excitation voltage, non-linearity, hysteresis, zero balance, input resistance, output resistance, temperature effect on both the output and zero balance, insulation resistance and cable length. The wiring color code is also included on the calibration data sheet.

6.3 Output

A load cell's output is not only determined by the weight applied, but also by the strength of the excitation voltage, and its rated mV/V full scale output sensitivity. A typical full scale output for a load cell is 3 millivolts/volt (mV/V). This means that for each volt of excitation voltage applied at full scale there will be 3 millivolts of signal output. If we have 100lbs applied to a 100lb load cell with 10 volts excitation applied the load cell signal strength will be 30mV. That is 10V x 3 mV/V= 30 mV. Now let's apply only 50lbs to the cell, keeping our excitation voltage at 10 volts. Since 50lbs is 50% or one half of full load, the cell signal strength would be 15mV.

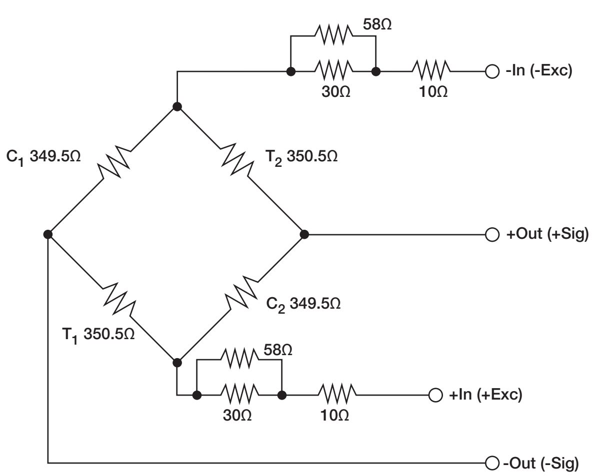


Figure 6-1. Wheatstone Bridge

The Wheatstone bridge shown in Figure 6-1 is a simple diagram of a load cell. The resistors marked T_1 and T_2 represent strain gauges that are placed in tension when load is applied to the cell. The resistors marked C_1 and C_2 represent strain gauges which are placed in compression when load is applied.

The +In and -In leads are referred to as the +Excitation (+Exc) and -Excitation (-Exc) leads. The power is applied to the load cell from the weight indicator through these leads. The most common excitation voltages are 10VDC, and 15VDC depending on the indicator and load cells used. The +Out and -Out leads are referred to as the +Signal (+Sig) and -Signal (-Sig) leads. The signal obtained from the load cell is sent to the signal inputs of the weight indicator to be processed and represented as a weight value on the indicator's digital display.

As weight is applied to the load cell, gauges C_1 and C_2 compress. The gauge wire becomes shorter and its diameter increases. This decreases the resistances of C_1 and C_2. Simultaneously, gauges T_1 and T_2 are stretched. This lengthens and decreases the diameter of T_1 and T_2, increasing their resistances. These changes in resistance cause more current to flow through C_1 and C_2 and less current to flow through T_1 and T_2. Now a potential difference is felt between the output or signal leads of the load cell.

Let's trace the current flow through the load cell. Current is supplied by the indicator through the -In lead. Current flows from -In through C1 and through -Out to the indicator. From the indicator current flows through the +Out lead, through C2 and back to the indicator at +In. In order to have a complete circuit we needed to get current from the -In side of the power source (Indicator) to the +In side. You can see we accomplished that. We also needed to pass current through the indicator's signal reading circuitry. We accomplished that as the current passed from the -Out lead through the indicator and back to the load cell through the +Out lead. Because of the high internal impedance (resistance) of the indicator, very little current flows between -Out and +Out.

Since there is a potential difference between the -In and +In leads, there is still current flow from -In through T_2 and C_2 back to +In, and from -In through C_1 and T_1 back to +In. The majority of current flow in the circuit is through these parallel paths. Resistors are added in series with the input lines. These resistors compensate the load cell for temperature, correct zero and linearity.

Let's look at a load cell bridge circuit in mathematical terms to help you understand the bridge circuit in both a balanced and unbalanced condition. Our Wheatstone bridge can either be drawn in a conventional diamond shape or as shown in Figure 6-2. Either way, it is the same circuit.

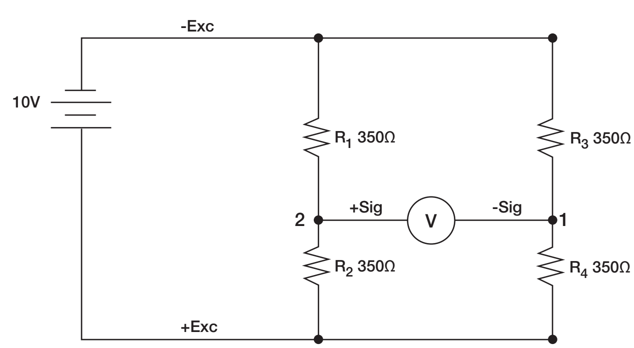


Figure 6-2. Wheatstone Bridge

We have replaced the ammeter with a voltmeter which will represent the display on our weight indicator. Also, the leads connected to our indicator are designated +Sig and -Sig. These represent our positive and negative signal leads. A 10 volt battery represents our indicator's power supply that provides the precise voltage to excite or power the load cell. The resistance values represent our four strain gauges which make up our load cell.

Since there is no load on our cell, all strain gauge resistances are the same. Using Ohm's Law we can figure the voltage drops at points 1 and 2. Each branch contains 350Ω + 350Ω = 700Ω of resistance. The current flow in the branch is the branch voltage divided by the branch resistance.

$$I_{R1+R2} = \frac{E_{R1+R2}}{R_1+R_2} = \frac{10V}{700\Omega} = 14.3mA \qquad I_{R3+R4} = \frac{E_{R3+R4}}{R_3+R_4} = \frac{10V}{700\Omega} = 14.3mA$$

To figure the voltage at point 1 we can use Ohm's Law.

$$E_{R3} = I_{R3}R_3$$

$$= 14.3mA \times 350\Omega$$

$$= 5V$$

Since all resistances are equal, the voltage at point 2 is also 5V. There is no voltage difference between points 1 and 2 thus a zero reading is displayed on our indicator.

7.0 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 the capacity too much, 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.

3.0mV/V x 10V = 30mV.

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

300

____ = .60 or 60%

500

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.

30mV x .6 = 18 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:

18000mV

__________ = 3.6µV/graduation

5000 grad

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 1000lb cell were in the given example instead of a 500lb cell, only 30% of the capacity would be used.

This would give a µV/graduation of

30mV x 30%

------------------------ = 1.8µV/graduation

5000 graduations

8.0 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:

4. Matched output load cells are used (as in the Paramounts).

5. Weighing self-leveling materials (liquids).

6. The vessel is partially supported on flexures.

*Assume that the vessel's center of gravity (see 2 and 3 above) 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.

8.1 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.

8.2 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 8-1 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.

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.

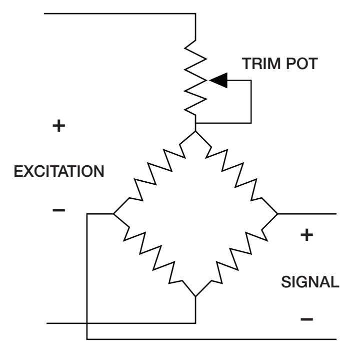


Figure 8-1. Excitation Trimming Load Cells

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 the load cell or on the label itself. 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 factor 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 is now trimmed.
5. Verify your results with certified test weights or a known amount of material.

8.3 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 8-2. 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.

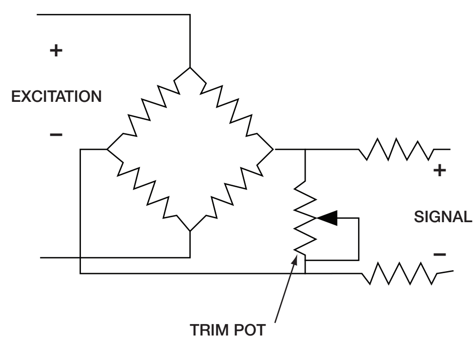


Figure 8-2. Signal Trimming Procedure

9.0 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.

The following example is based on the premise that a power supply of exactly 10V DC is used. Measure your power supply for the exact excitation voltage to obtain your results.

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:

   Total Load Cell mV/V Output = Simulator mV/V Setting
   Total Load Cell Capacity Displayed Weight
   For example:
   If four 5,000lb 3 mV/V load cells are used for a 10,000lb capacity scale, the simulator setting expected when 10,000lb is placed on the scale can be determined by the following:

   3.0 mV/V = Simulator mV/V Setting
   ------------ --------------------------
   20,000lb 10,000lb

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

5. Adjust the indicator to display the capacity of the scale (10,000lb in our example) and set the indicator's span.
6. Adjust the simulator's output in steps (1.0mV/V, 0.5mV/V, 0.0mV/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 5½ 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.

10.0 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.

10.1 Environment

- 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 Section 20.3 on page 42 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.

10.2 Load Cell and Mount

- Choose load cells with accuracy that is consistent with the desired system accuracy.
- Do not grossly oversize the load cells; see Section 4.2 on page 6. The 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 Section 19.0 on page 36.
- Use proven load cell mounts that will provide optimal loading conditions.
- Orient the mounts as recommended in the installation manual.

10.3 Mechanical/Structural Considerations

- 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.

10.4 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.

10.5 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.

11.0 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 4½ digit ohm meter. The tests are: physical inspection, zero balance, bridge resistance and resistance to ground.

11.1 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 appear good, then you need to look at specifics: sealing areas, the element itself, and the cable.

In most load cells, 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 (Figure 11-1 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 (Figure 11-1 point B) for signs of contamination.

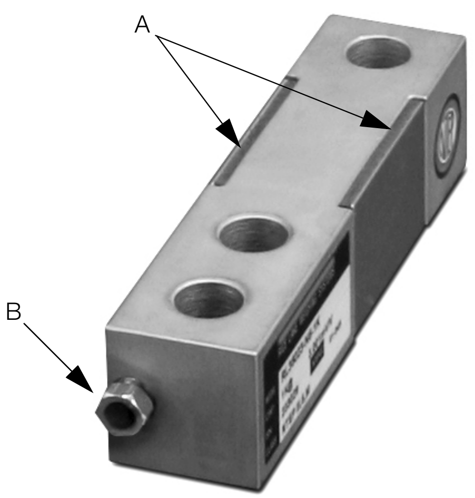


Figure 11-1.

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.

11.2 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.

11.3 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.

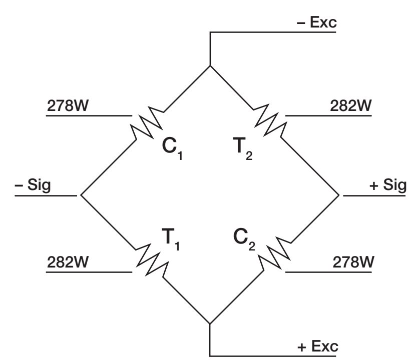


Figure 11-2.

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, in Figure 11-2, 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:

- T1(–Sig, +Exc) = 282Ω
- C1(–Sig, –Exc) = 278Ω
- T2(+Sig, –Exc) = 282Ω
- C2(+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. C1=T2
2. T1=C2
3. (C1 + T1) = (T2 + C2)

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%.*

11.4 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 50VDC 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 5000MΩ, 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 5000MΩ), 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.

12.0 Mounting Assemblies and Compatible Load Cells

Mount	Compatible Load Cells	Range	NTEP	Material	Finish	Protection	Matched Output	Comments
ITCM	RL20000	25-20,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	Used for suspended tank, hopper and vessel weighing, and electro-mechanical conversion.
	RL20000ST	25-20,000 lb	Yes	Stainless Steel	Nickel Plated	Environmental	—	
	RL20000SS	50-10,000 lb	Yes	Stainless Steel	—	Environmental	—	
	363	50-10,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	9363	50-10,000 lb	Yes	Stainless Steel	—	Environmental	—	
ITCM	RL20001	250-20,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	60001	250-20,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	60050	250-20,000 lb	No	Stainless Steel	—	Environmental	—	
RL50210 TA	RL50210	50-250 lb	No	Alloy Steel	Nickel Plated	Environmental	—	
	60040	50-250 lb	No	Alloy Steel	Nickel Plated	Environmental	—	
RL50210 TA	RL30000	250-2,500 lb	Yes	Alloy Steel	Nickel Plated	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 Plated	Environmental	—	
	RL35083	1,000 & 2,500 lb	No	Stainless Steel	—	Welded	—	
	5123	1,000 & 2,500 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	9123	1,000 & 2,500 lb	No	Stainless Steel	—	Environmental	—	
	65023	500-2,500 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	65023	500-2,500 lb	No	Stainless Steel	—	Environmental	—	
	65083	1,000-2,500 lb	No	Stainless Steel	—	Welded	—	
	RL35082	1,000 - 2,500 lb	Yes	Stainless Steel	—	Welded/Hermetic	—	
RL1800	RL30000	250-10,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	Used for low-to medium capacity tank, hopper and vessel weighing.
	RL39123	250-10,000 lb	No	Stainless Steel	—	Environmental	—	
	RL35023	1,000-10,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	RL39523	1,000-10,000 lb	No	Stainless Steel	—	Welded	—	
	RL35083	1,000-10,000 lb	No	Stainless Steel	—	Welded	—	
	5123	1,000-10,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	9123	1,000-10,000 lb	No	Stainless Steel	—	Environmental	—	

Table 12-1. Mounting Assemblies and Compatible Load Cells

	65023	1,000-10,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	65023-0113	1,000-10,000 lb	No	Stainless Steel	—	Environmental	—	
	65083	1,000-10,000 lb	No	Stainless Steel	—	Hermetic	—	
RL1900	SSB	1,000-10,000 lb	Yes	Stainless Steel	—	Welded	—	Used for low-to-medium capacity tank, hopper and vessel weighing.
	SB3	1,000-10,000 lb	No	Alloy Steel	Nickel Plated	Environmental	—	
	RLSSB	1,000-10,000 lb	Yes	Stainless Steel	—	Welded	—	
RLC	RLC	500-5,000 kg	No	Stainless Steel	—	Hermetic	—	Used for low-to-medium capacity tank, bin and hopper weighing
Paraounts®	SB4	1125-22,500 lb (5KN-100KN)	Yes	Stainless Steel	—	Hermetic	Yes	Used for low-to-medium capacity tank, hopper and vessel weighing.
	JB5	1125-22,500 lb (5KN-100KN)	Yes	Stainless Steel		Environmental	Yes	
	SB10	2.3k	No	Stainless Steel		Hermetic	Yes	

Table 12-1. Mounting Assemblies and Compatible Load Cells (Continued)

13.0 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.

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.

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.

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.

Load Distribution

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

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.

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.

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.

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.

Swaying in a Suspended Vessel Scale

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

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.

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.

Cap screw diameter	Recommended Torque (ft lb)			
	Heat-treated 1038 hex head SAE Grade 5		Alloy hex head SAE Grade 5	
	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
1/4"	11	13	12	15

Table 13-1.

NOTES: *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. General formula for calculating torque is as follows: Torque in Inch/lbs = 0.2 x Nominal Diameter of Screw x Load in lbs, where load = 80% of yield strength, expressed in lb, not pounds per square inch. The tension induced in a cap screw may be checked by measuring overall length before torquing*

14.0 Weigh Modules: Single-Ended Beam

14.1 Introduction

Single-ended beam load cells offer many advantages when used in well-designed weigh modules. Modules using single-ended 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.

14.2 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 hardened 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 14-1, or may be hung from below).
- The load introduction 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.

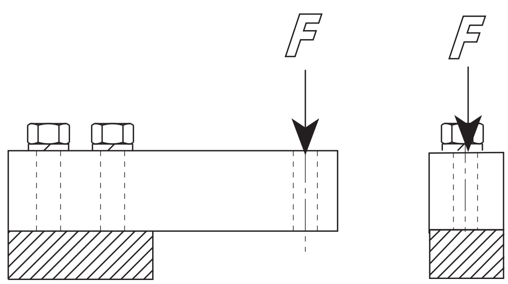


Figure 14-1.

14.3 Single-End Beam Orientation

Figure 14-2 illustrates four different vessels and recommended mounting configurations for single-ended beam weigh modules. See the Section 14.9 on page 25 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).

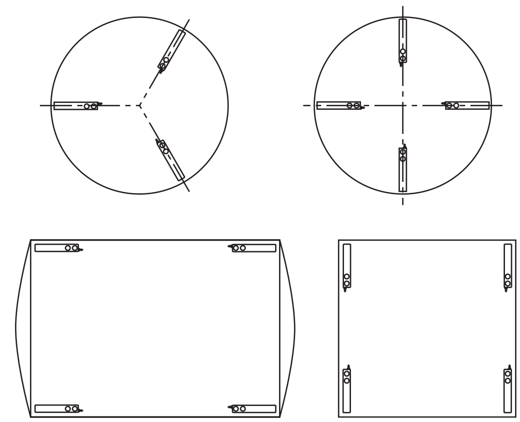


Figure 14-2.

14.4 SURVIVOR® 1700HE Modules

These light- to- medium capacity modules use single-ended beam load cells in capacities from 5kg-250kg (11-550lb) and 500-5,000kg (1,100-11,00lb). 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 resistance, moisture ingress and mechanical protection. The load cells are waterproof guaranteed and OIML C3 certified (20kg-5,000kg) to offer the ultimate in durability and accuracy.

Allowable Movement

Figure 14-3 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.

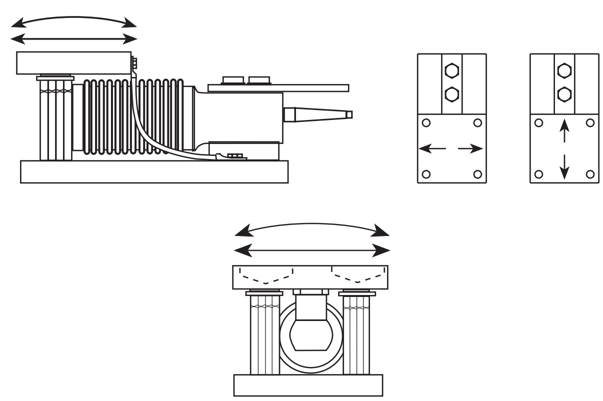


Figure 14-3. SURVIVOR 1700HE

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 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 as shown in Figure 14-4.

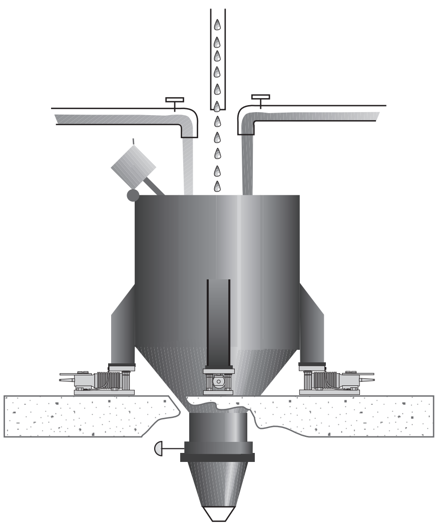


Figure 14-4. SURVIVOR 1700HE in Micro-Ingredient Batching

14.5 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 14-5 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.

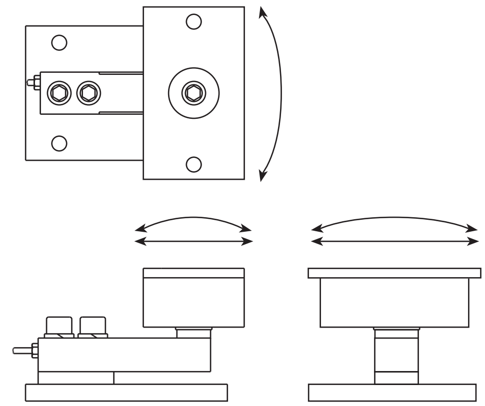


Figure 14-5. RL50210 TA

Construction and Features

1. The module has a large base plate and spacer washer, and the load cell is attached or bolted 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 2,500 lb accommodate an RL50210 load cell while capacities 500 lb to 2,500 lb accommodate an RL35023 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. See Figure 14-6.

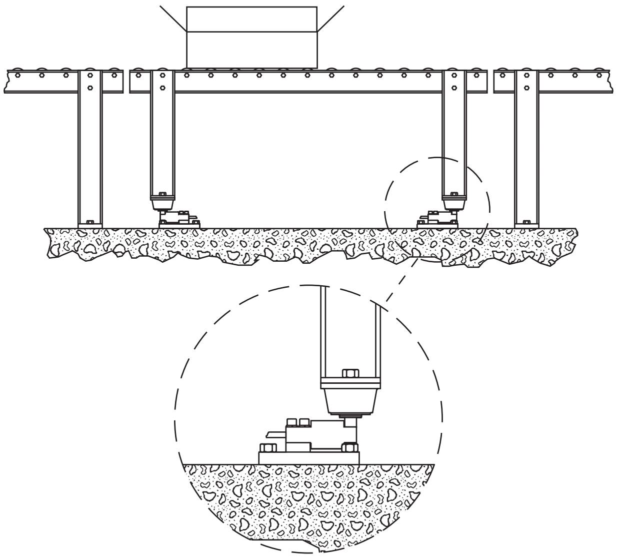


Figure 14-6. RL50210 TA on Conveyor

14.6 RL1800 Modules

These modules use single-ended 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.

RL1800 modules allow the installer to adjust overall height easily with a 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. See Figure 14-8.

Allowable Movement

Figure 14-7 illustrates the RL1800 module with arrows indication allowable movement.

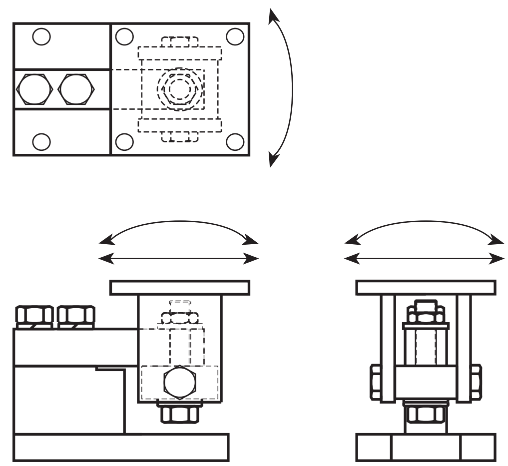


Figure 14-7. RL1800

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 14-7.
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.

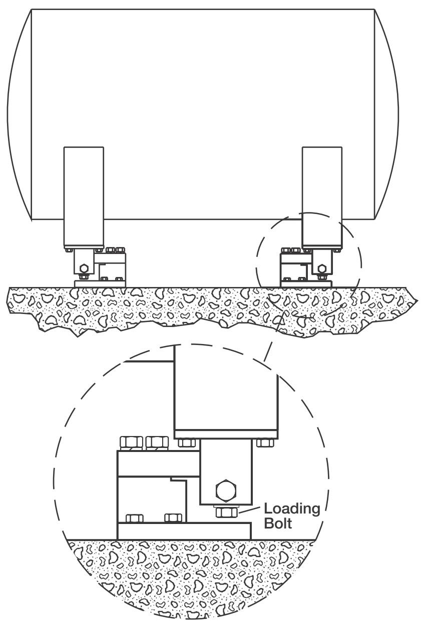


Figure 14-8. RL1800 and 1855 HE Modules on Horizontal Cylindrical Tank

14.7 SURVIVOR® 1855HE Modules

These modules use single-ended stainless steel welded 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.

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. See Figure 14-8.

Allowable Movement

Figure 14-9 illustrates the 1855HE module with arrows indication allowable movement.

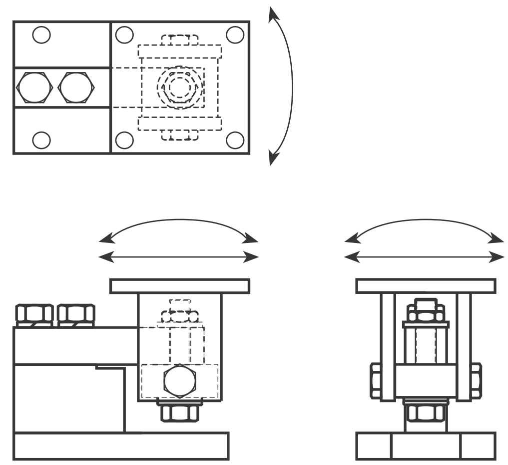


Figure 14-9. SURVIVOR 1855HE

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 14-9.
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 PTFE-jacketed cable and integral conduit adapter heighten chemical and moisture resistance.

14.8 RL1900 Modules

The RL1900 module is similar in design to the RL1800, but accommodates slightly more lateral movement than the RL1800. See Figure 14-10.

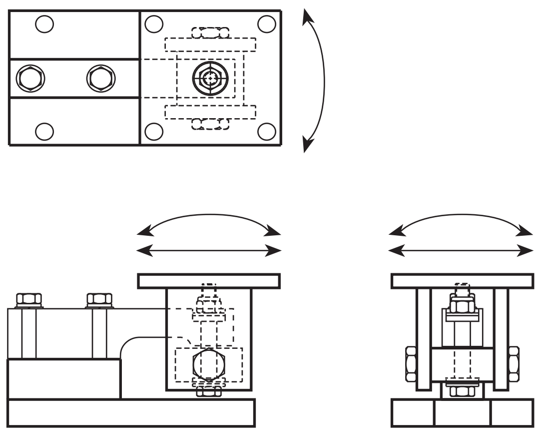


Figure 14-10. RL1900 Modules

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 14-10.
4. This module allows slightly 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 stainless steel.
9. This module can accommodate both environmentally protected and hermetically sealed load cells—the RLSSB, the HBM SB3 and the Vishay RTI SSB.

Typical Installation

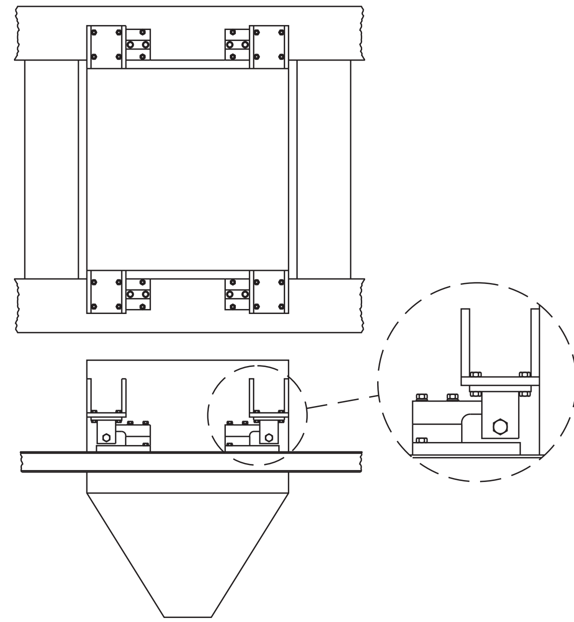


Figure 14-11. RL1900 Modules on Hopper Scale

14.9 Paramounts® HS and 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, SB10 and 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.

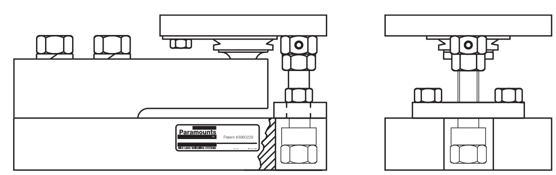


Figure 14-12.

Allowable Movement

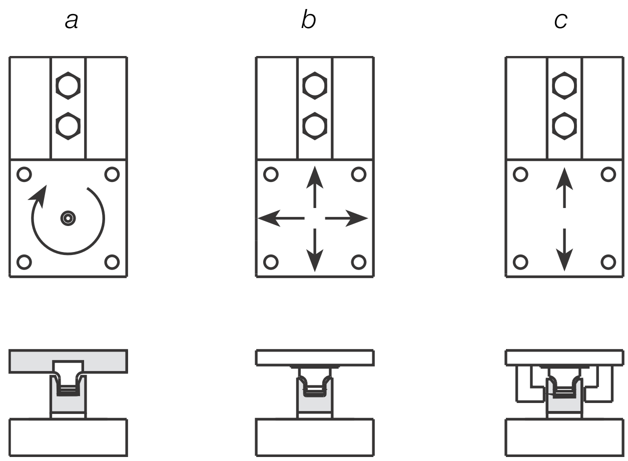


Figure 14-13. The Three Module Designs of the Paramounts System Include the (a) Fixed-Pin Module, (b) Free-Sliding Module, and (c) Side-Stop Module

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 the 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 PTFE-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 PTFE-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, SB10 and SB5 load cells incorporate a blind hole for load introduction. The load is introduced via a convex loading pin. 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 Flintec sensing section. Therefore, torsional effects are virtually eliminated.
2. Jacking Screw and Lift-Off Protection: Each module consists of a base plate to which the load cell is attached and a top plate through which the load is introduced. 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, SB10 and SB5 load cells are matched output, stainless steel load cells. All Paramounts load cell kits use SB, SB10 and SB5 load cells with outputs matched to ±.07%. This eliminates 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.

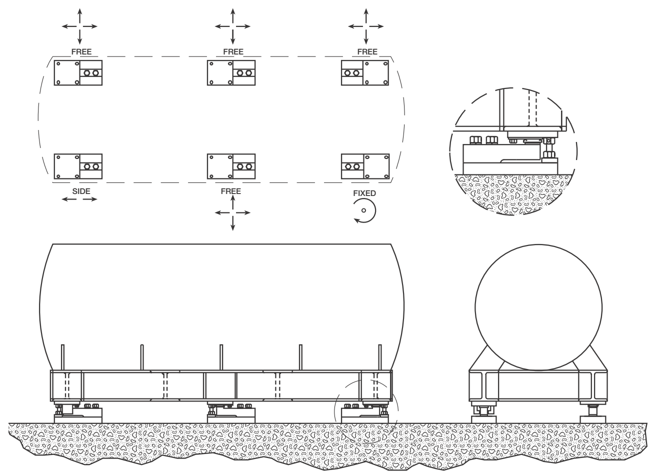


Figure 14-14. Paramounts Mounting System on Cylindrical Tank

Typical Applications

A three-module system would use one of each module. Scales requiring more than three modules use additional free-sliding modules. Figure 14-15 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 ensures that the vessel's expansion/contraction is unrestricted in either direction.

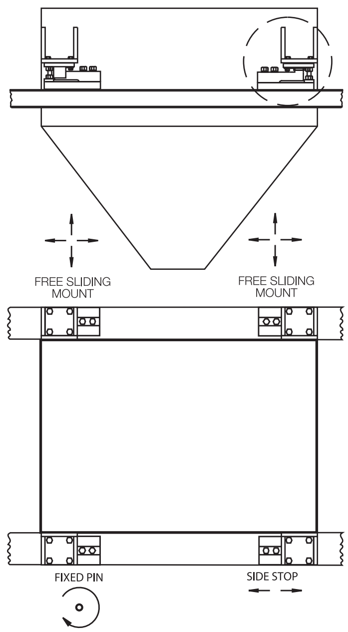


Figure 14-15. Paramounts on Suspended Hopper

15.0 Weigh Modules: Double-Ended Beam

15.1 Introduction

Double-ended 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 MVS mounting systems.

Figure 15-1 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.

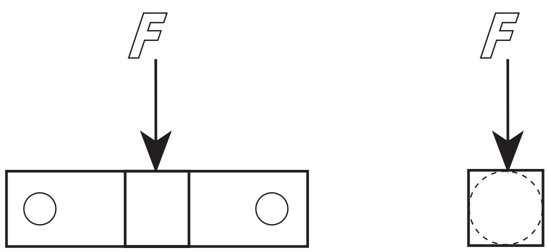


Figure 15-1.

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.

Double-End Beam Orientation

In Figure 15-2, we illustrate some recommended mounting methods for double-ended shear beams used in the RL1600 and EZ Mount 1.

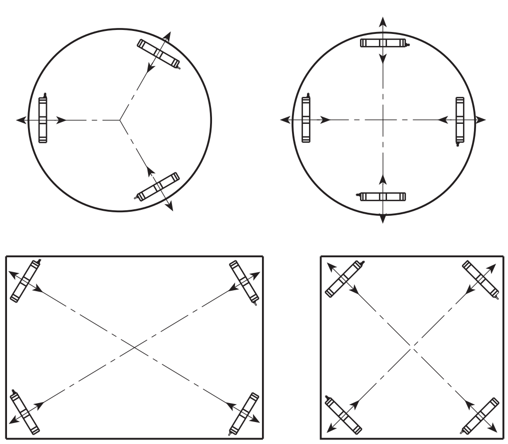


Figure 15-2.

15.2 RL1600 Modules

These assemblies are suitable for medium- to heavy-capacity applications because of the inherent strength and stability of the double-ended center-loaded cell which is 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 only 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

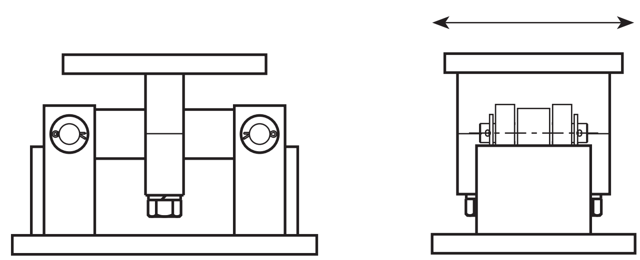


Figure 15-3.

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.
3. The module is self-checking in all directions.
4. It is available in mild steel and stainless steel construction in capacities from 1,000lb to 75,000lb, and in cast iron from 1,000lb to 25,000lb. It may be used with RL75016 load cells in alloy steel or stainless steel.

Typical Application

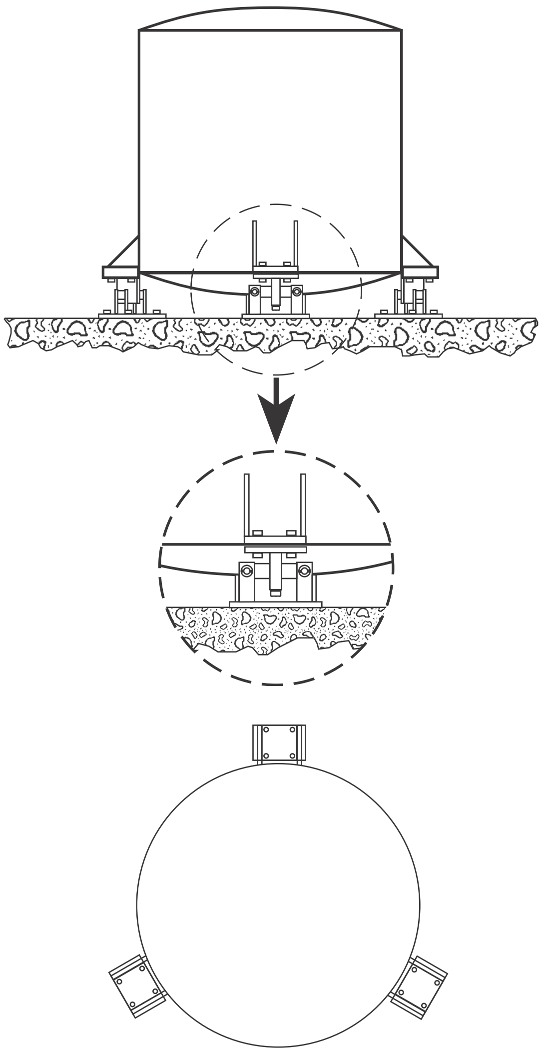


Figure 15-4. RL1600 Modules on Low-Profile Tank

15.3 SURVIVOR® 2100HE Modules

These medium- to heavy-capacity modules are available in two sizes in capacities ranging from 20,000-100,000lb. 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 by utilizing the RL75060S stainless steel load cell.

Allowable Movement

Figure 15-5 illustrates the 2100HE module's capability to handle movement.

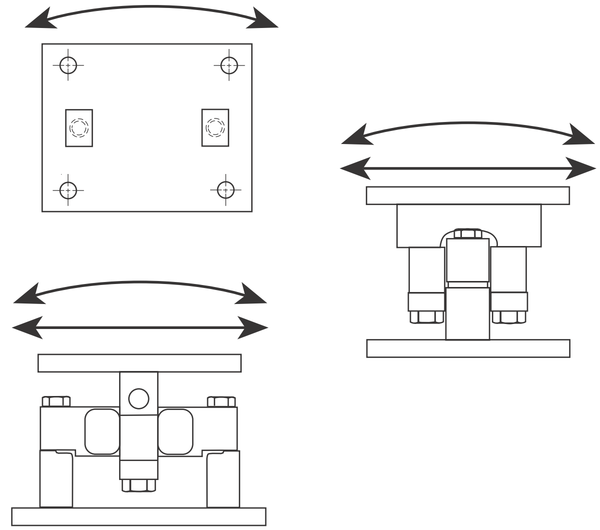


Figure 15-5. SURVIVOR 2100HE

Construction and Features

1. IP67 environmental rating to protect 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. PTFE jacketed cable is standard for maximum chemical resistance.
5. All modules come standard in stainless steel.
6. Internal lift-off protection and checking eliminates extraneous hardware.

Typical Application

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

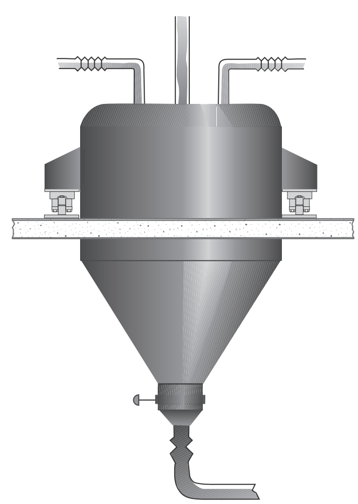


Figure 15-6. SURVIVOR 2100HE in Heavy-Capacity Application

15.4 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 and 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

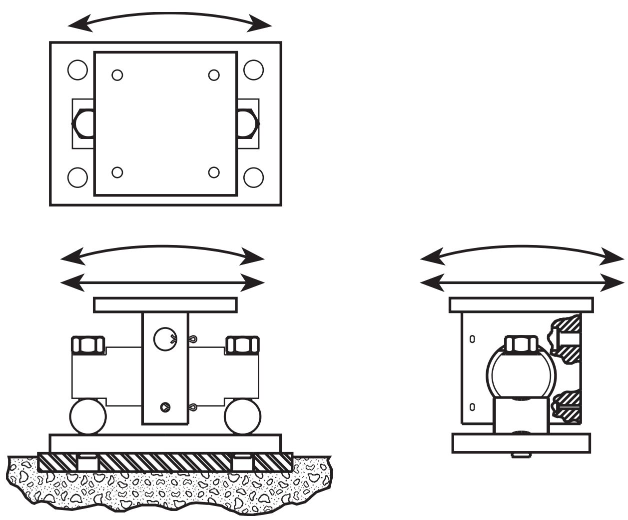


Figure 15-7.

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 15-7, 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, RL70000SS, RL71000HE or Vishay RTI 5103 and the stainless steel Vishay RTI 9103.

Typical Application

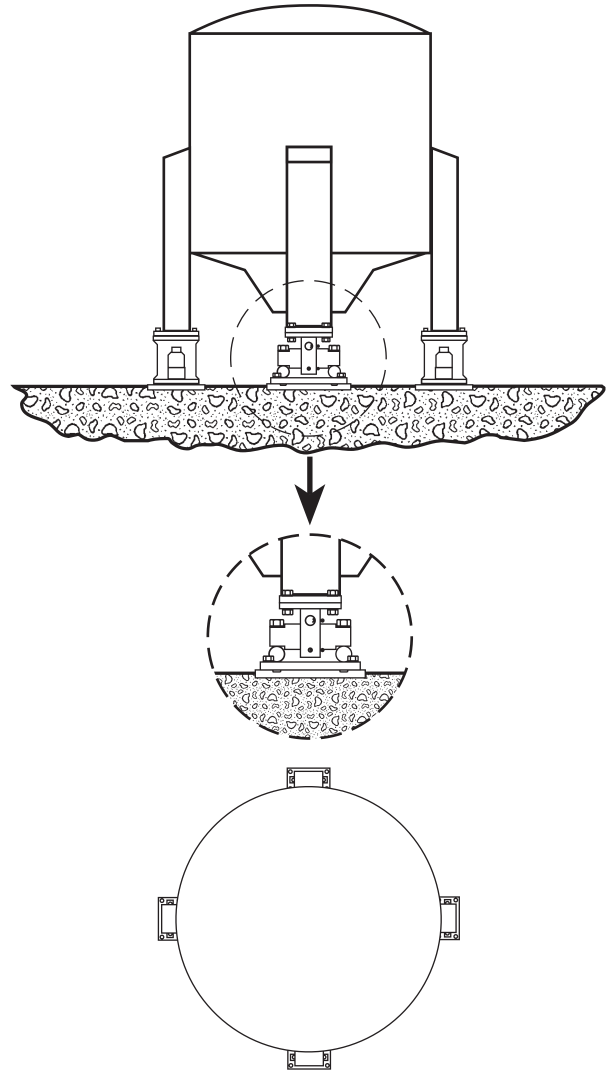


Figure 15-8. EZ Mount 1 Weigh Module Arrangement

15.5 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-ended 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

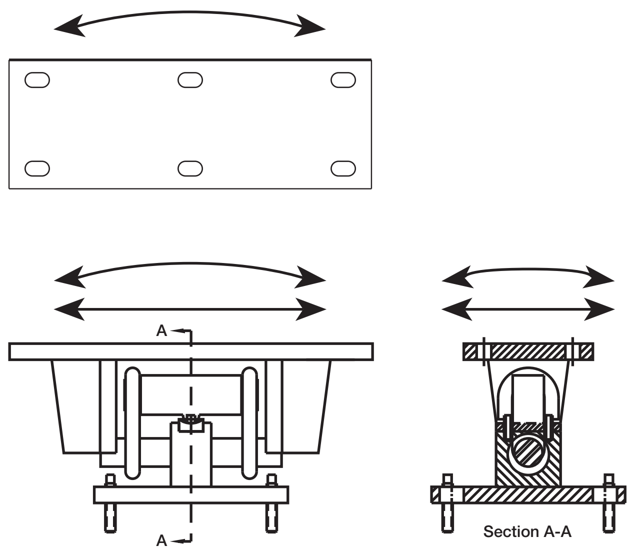


Figure 15-9.

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 15-9.
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 to suited 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 also 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 23,000 lb to 75,000 lb, and the RL75223 and RTI 5223 in capacities from 50,000 lb to 100,000 lb.

Typical Application

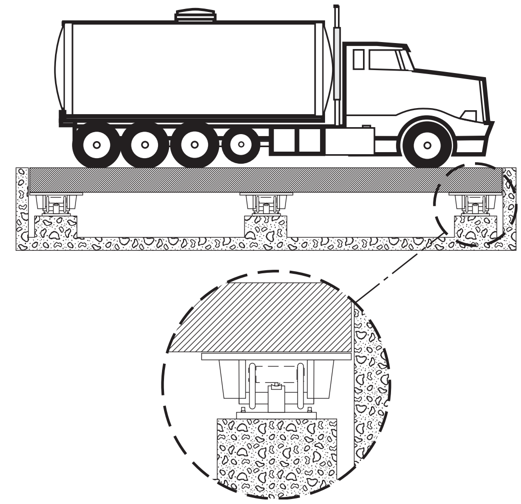


Figure 15-10.

15.6 MVS Truck Scale Modules

The MVS 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 center-link design provides freedom of movement in the longitudinal direction while also self-centering, making this module ideal for vehicle scales.

Unlike the double-ended beams used for the RL1600 or EZ Mount 1, the MVS 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.

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.
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 mild steel MVS modules use the RL75058 double-ended shear beam load cell, which is made of high alloy steel.

16.0 Weigh Modules: Compression Canisters

16.1 Introduction

When mounts are needed in capacities over 100,000 lb, canister load cell mounts are one of the choices available. 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 500,000lb per mount assembly, most canister mounting assemblies require more 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.

16.2 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.

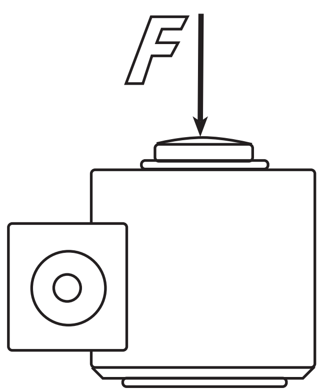


Figure 16-1.

16.3 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 harshest environments.

Allowable Movement

The RLC mount shown in 16-2 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.

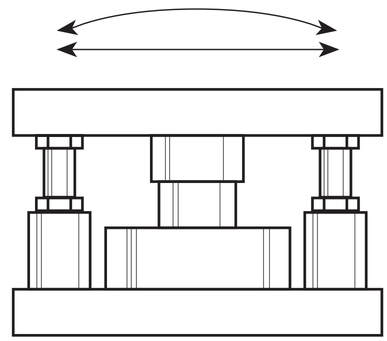


Figure 16-2.

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.

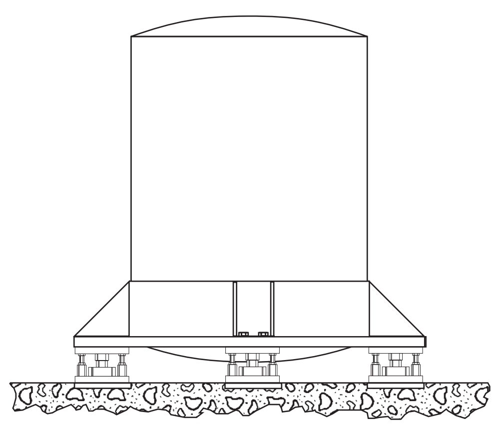


Figure 16-3.

17.0 Weigh Modules: Tension Mounting (S-Beam)

17.1 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.

17.2 General Mounting Principles

Figure 17-1 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 17-1.
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.

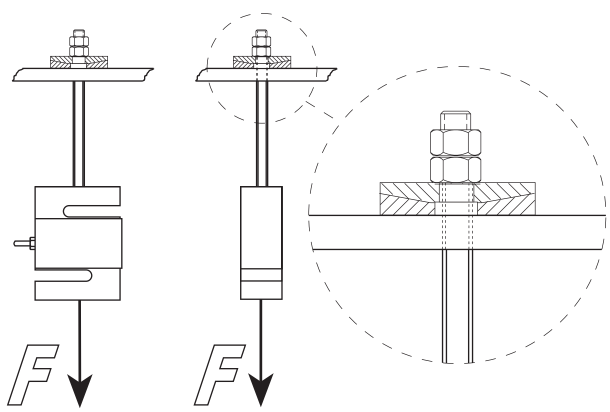


Figure 17-1.

ITCM Mounts

The ITCM assembly is a particularly convenient method of suspending a weigh vessel. The combination of clevises and rod-end ball joints ensure 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 17-2 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.

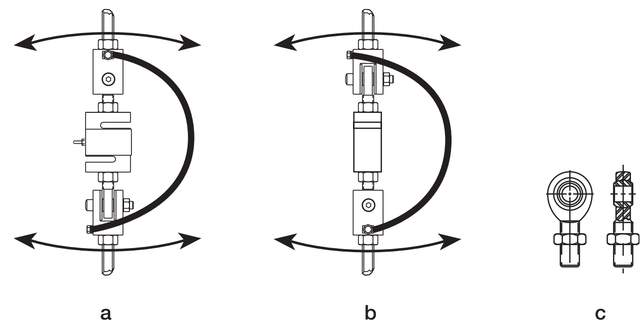


Figure 17-2.

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 17-2(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. ITCMs are available in mild steel in capacities from 100lb to 20,000lb using the RL20000 load cell. Stainless steel versions are available in capacities from 100lb to 5,000lb
6. 20,000lb ITCM assemblies do not have TFE lined rod end ball joints.

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 17-3 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.

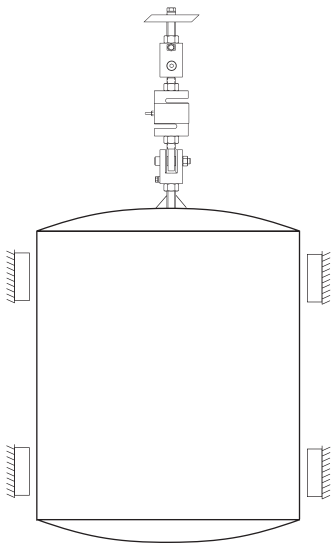


Figure 17-3.

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.

The three load cell suspension system shown in Figure 17-4 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 vibrations, agitation, wind or seismic activities 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.

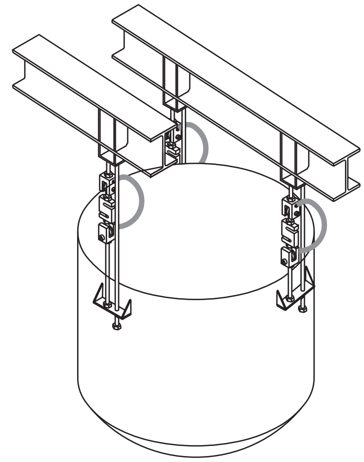


Figure 17-4.

The 4-cell suspension system shown in Figure 17-5 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.

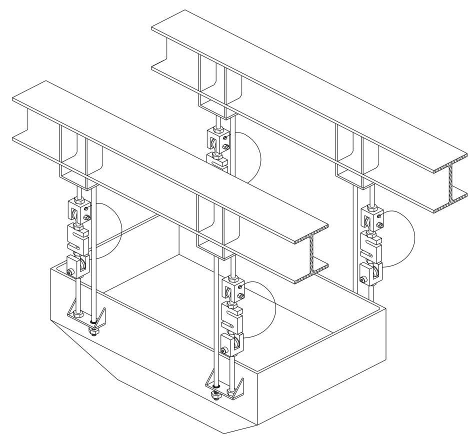


Figure 17-5.

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.

18.0 Mounting Assemblies and Compatible Load Cells

Mount	Compatible Load Cells	Range	NTEP	Material	Finish	Protection	Matched Output	Comments
RL1600	RL75016	1,000-75,000 lb	No	Alloy Steel	Nickel Plated	Environmental	—	Used for low-to-high capacity tank, hopper and vessel weighing.
	65016	1,000-75,000 lb	No	Alloy Steel	Nickel Plated	Environmental	—	
	RL75016SS	1,000-75,000 lb	No	Stainless Steel	—	Environmental	—	
	65016W	1,000-75,000 lb	No	Stainless Steel	—	Environmental	—	
	RL75016WHE	1,000-25,000 lb	No	Stainless Steel		Hermetic	—	
EZ Mount 1	RL70000	5,000-250,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	Used for high-accuracy medium-to high-capacity tank, hopper and vessel weighing,
	5103	5,000-250,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
	9103	5,000-150,000 lb	No	Stainless Steel	—	Environmental	—	
	RL71000HE	5,000-60,000 lb	No	Stainless Steel		Hermetic	—	
Translink™	RL75040	25,000-75,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	Used for livestock and vehicle scales & high-capacity tank scales
	65040	25,000-75,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
Translink™	RL75223	50,000-100,00 lb	Yes	Alloy Steel	Nickel Plated	Welded	—	
	5223	50,000-100,00 lb	Yes	Alloy Steel	Nickel Plated	Welded	—	
MVS	RL75058	10,000-100,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	Used for livestock, vehicle scales and high-capacity tank scales
	65058	10,000-100,000 lb	Yes	Alloy Steel	Nickel Plated	Environmental	—	
MagnaMount™	CP	10,000-200,000 lb	No	Stainless Steel		Hermetic	—	Used for high capacity vehicle scales including railroad track. Also used for high-capacity tank scales.
	CSP	10,000-200,000 lb	Yes**	Stainless Steel		Hermetic	—	
65092 TWA	65094	50,000-500,000 lb		Alloy Steel	Nickel Plated	Environmental	—	Used for high-capacity tank and silo weighing

*Excluding 15,000 lb
**Excluding 10,000 lb

Table 18-1.

19.0 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 19-1 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 19-2 is an example of a circular vessel suspended from one load cell and two flexures (or simply tension rods in this case).

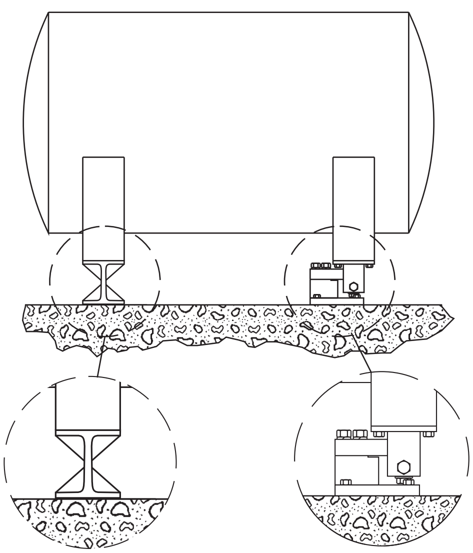


Figure 19-1.

Care must be taken to separate the flexures and load cells to opposite sides or ends of the vessel. In Figure 19-2, 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.

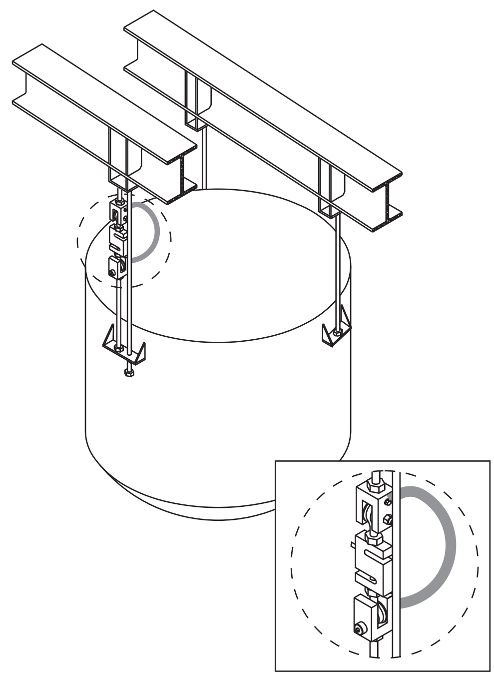


Figure 19-2.

20.0 Attaching Piping to Weigh Vessels

20.1 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 20-1 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.

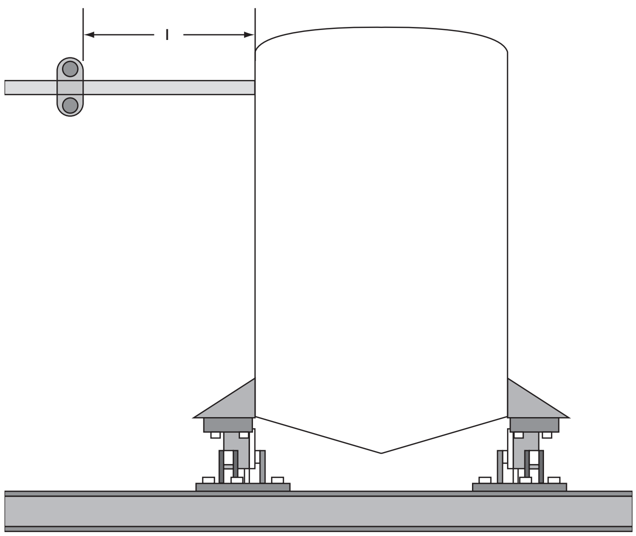


Figure 20-1.

When the vessel is loaded, it moves downward as shown in Figure 20-2 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.

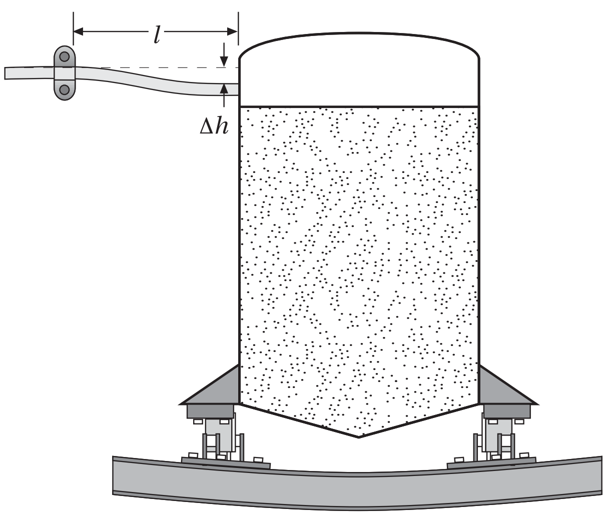


Figure 20-2.

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

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 exerted 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 next example 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 F1 is exerted upward on the vessel?

20.2 Piping Guidelines

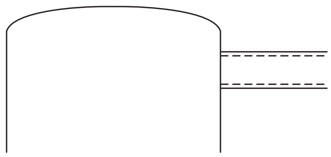
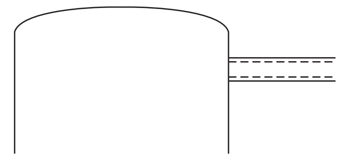
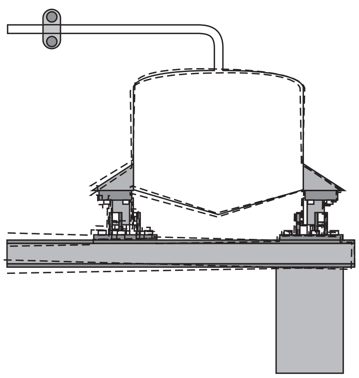
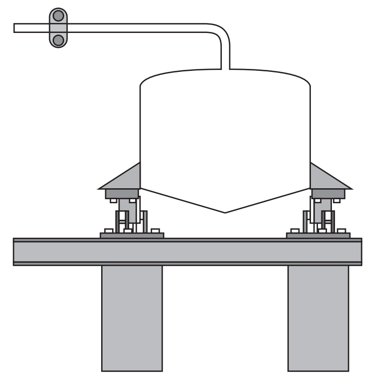
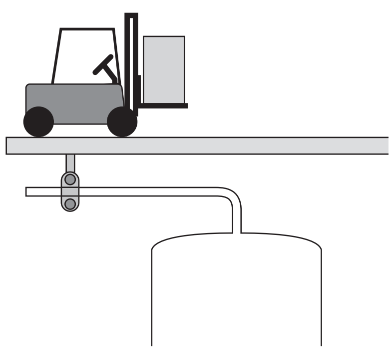
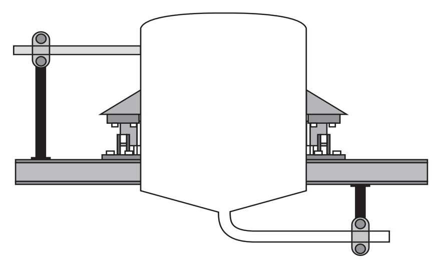
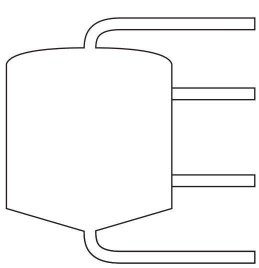
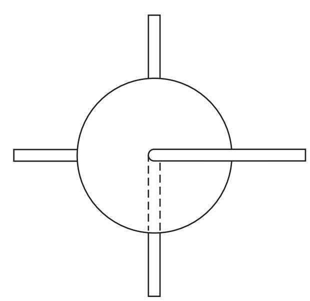
Incorrect	Piping Guidelines	Correct
	Use the smallest diameter pipe suitable for the application.	
	Use the lightest wall pipe suitable for the application.	
	Avoid tilting of the weigh vessel as a result of non-uniform support stiffness. Small rotations of the vessel can be amplified into large movements at the first support.	
	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.	

Table 20-1. Piping Guidelines

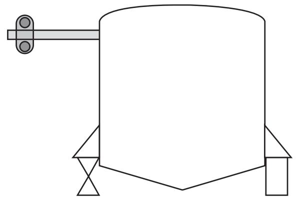
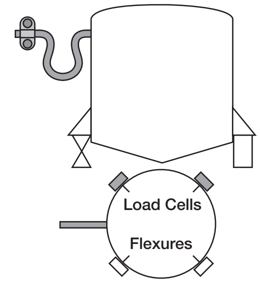
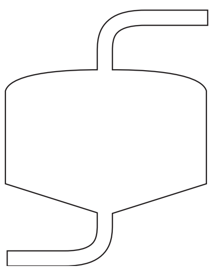
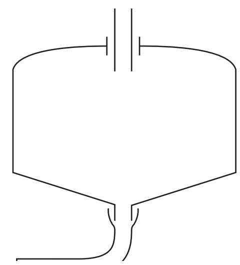
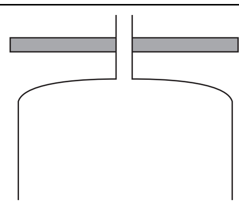
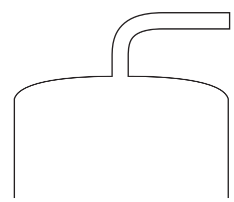
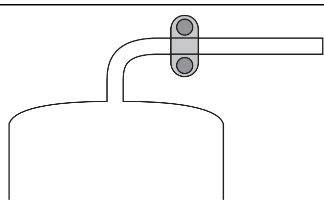
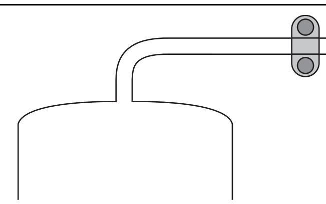
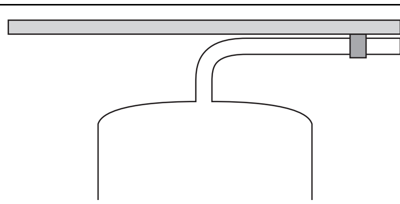
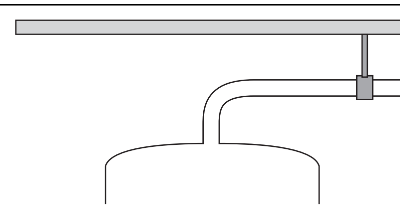
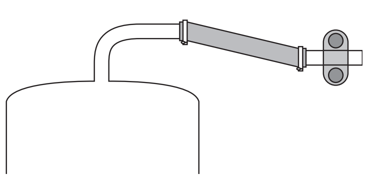
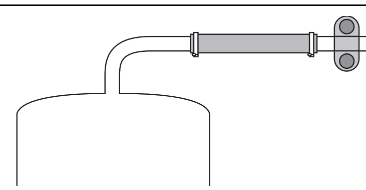
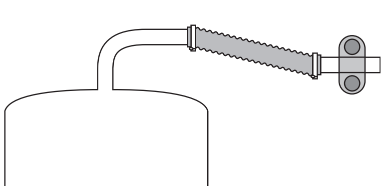
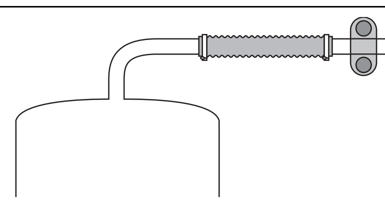
Incorrect	Piping Guidelines	Correct
	When attaching pipes to a vessel partially mounted on flexures, extra care must be exercised to avoid side forces induced by thermal expansion/contraction of the pipes. Use flexible hose, bellows, or a loop, and attach the pipes relative to the load cells/flexures, as shown, to minimize the transfer of weight from the flexures to the cells or vice versa.	
	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, particularly when they are restrained from vertical movement. 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. Do not use the flexible hose to compensate for an initial offset in the pipes.	
	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.	

Table 20-1. Piping Guidelines (Continued)

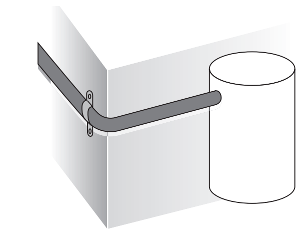
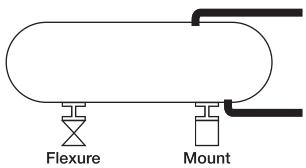
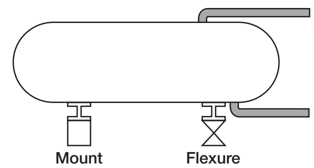
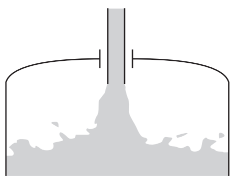
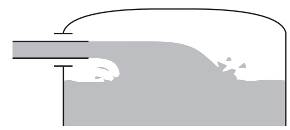
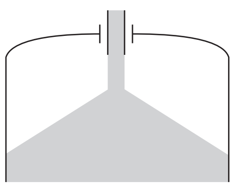
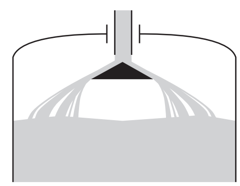
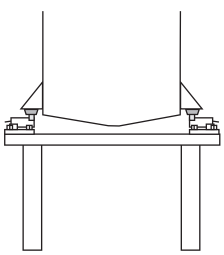
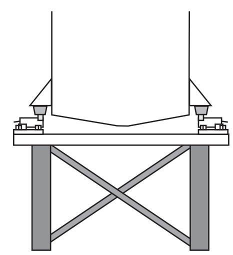
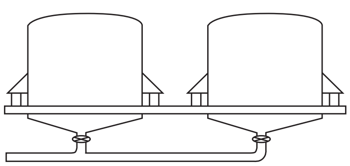
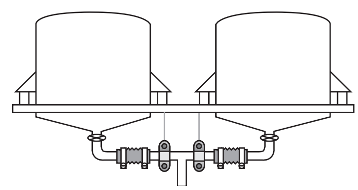
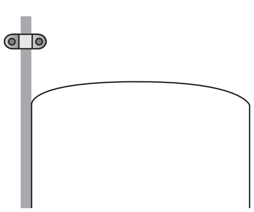
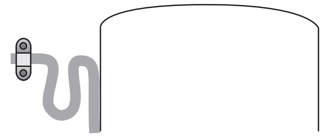
Incorrect	Piping Guidelines	Correct
	Placing a right angle bend in the pipe in a horizontal plane greatly reduces the stiffness of the pipe.	
	With horizontal vessels partially mounted on flexures, do not attach pipes at the live end. Attach pipes over the flexures if possible, since any vertical forces 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.	
	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.	

Table 20-1. Piping Guidelines (Continued)

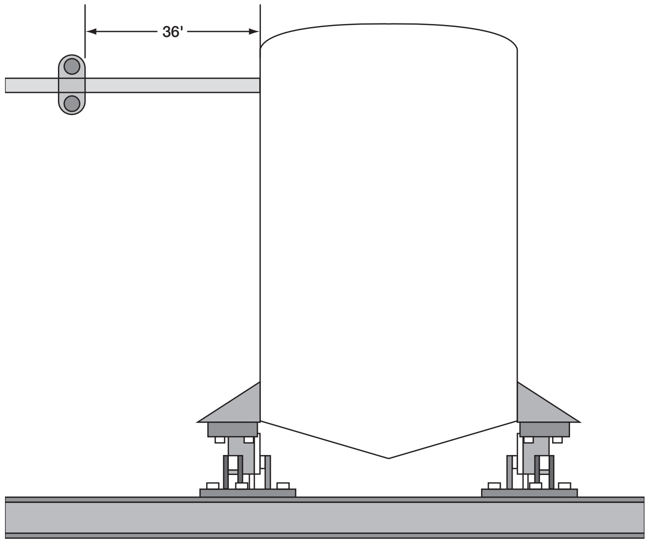


Figure 20-3.

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:

$$F1 = \frac{.59(4.50^4 - 4.03^4) \times .258 \times 29{,}000{,}000}{36^3}$$

= 13,840 lb.

The first line of Table 20-2 (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 F1 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 F1 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 20-2 that F1 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 Section 20.2 on page 38. 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 = F1 + F2 + F3 …

where F1 is the force exerted by pipe 1, F2 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:

$F \leq .1 \times$ system accuracy (in%) x live load (lb)

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 1,250lb.

Example	Pipe	Pipe Length (l)	Deflection (Δh)	Upward Force (F1)	Percentage Reduction in (F1)
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%

Table 20-2.

* For 4” Schedule 10S, D=4.50, d=4.26; †For 2” Schedule 40, D=2.38; d=2.16

Example 2

The vessel shown in Figure 20-4 has the following characteristics:

- 40,000lb live load
- Mounted on 4 each 20,000lb single-ended beams with full scale deflections of .010"
- Structure deflection of .375"
- Accuracy requirement of 0.5%
- Material is stainless steel throughout

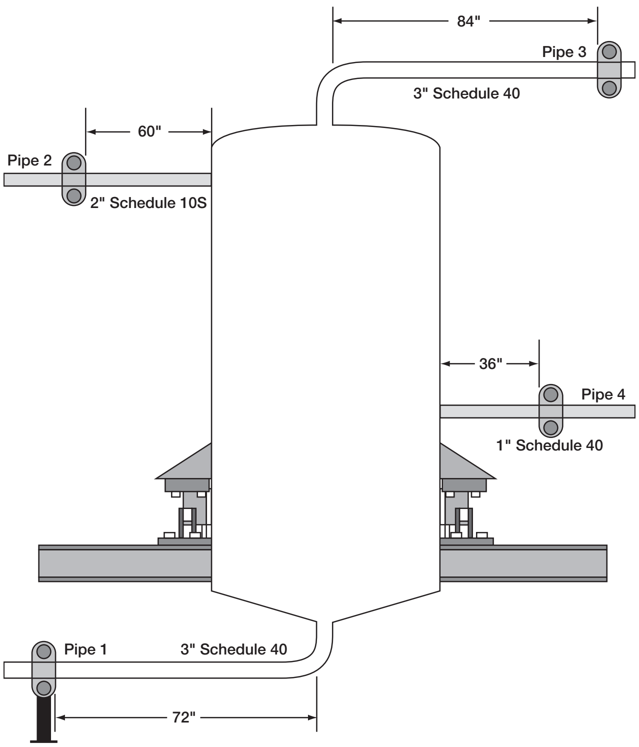


Figure 20-4.

1. Determine allowable F value from equation 2,
   $F \leq .1 \times$ system accuracy (%) x 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 2,000lb.
2. Determine total deflection. Since the live load represents only ½ 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"
3. Determine F_X for each pipe using the formula:

$$F_X = \frac{.59(D^4 - d^4) \times (Dh) \times E}{l^3}$$

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

$$= 1{,}029\text{lb}$$

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

$$= 391\text{lb}$$

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

$$= 648\text{lb}$$

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

$$= 239\text{lb}$$

4. Determine F using the formula: F = F1 + F2 + F3 + F4
   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%).
- Reduce the deflection of the support structure.
- Improve the piping by:
  - using smaller, lighter pipes
  - use flexible hose or bellows
  - 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 = 697lb. Hence, F = 697 + 391 + 648 + 239 = 1,975lb.

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

20.3 Vessel Restraint Systems

While many of the mounting arrangements offered by Rice Lake Weighing Systems 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.

20.4 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 20-5. 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 20-6 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 over-tighten. 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.

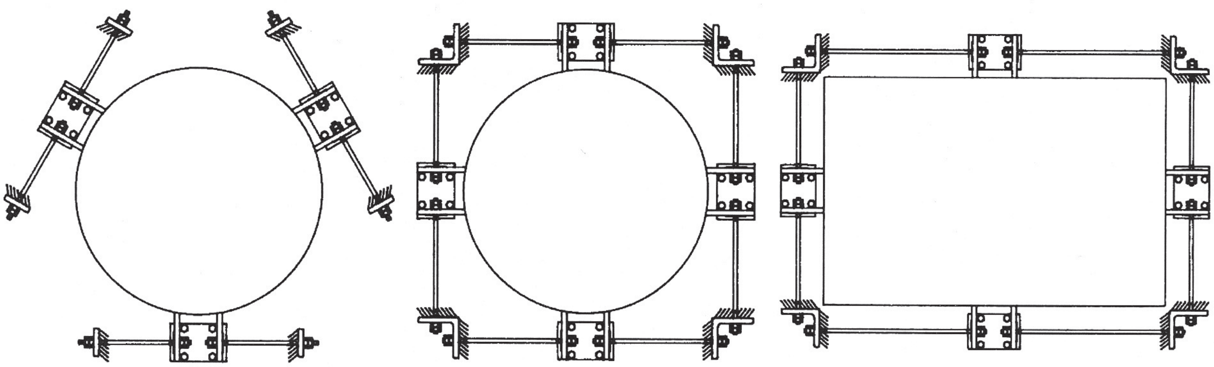


Figure 20-5.

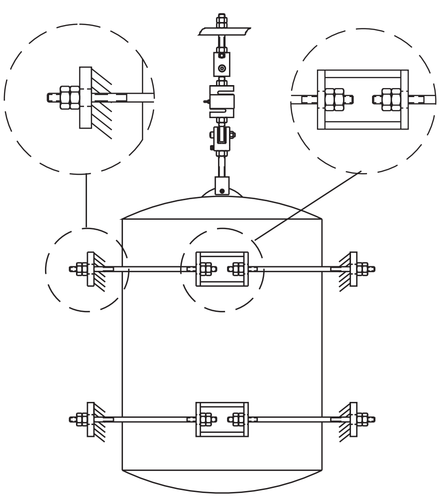


Figure 20-6.

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.

20.5 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:

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

As shown in Figure 20-7 (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.

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 20-7 (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 20-7 (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 Section 21.0 on page 45

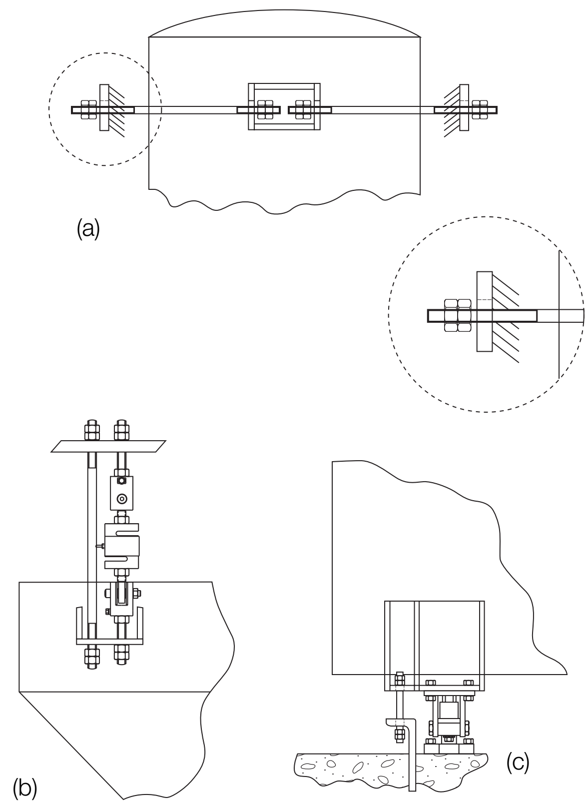


Figure 20-7.

21.0 Calculating Thermal Expansion of Vessels and Stay Rods

21.1 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 21-1 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:

$\Delta L = a \text{ x } L \text{ x } \Delta T$

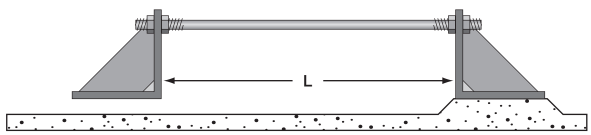


Figure 21-1.

The coefficient of thermal expansion (a) for various materials is used to construct vessels and stay rods.

Example:

If the rod in Figure 21-2 is made from 1018 steel, then a = 6.5 x 10-6. If the rod is 48" long and the temperature increases by 60°F, the length of the rod will increase by:

$\Delta L = a \text{ x } L \text{ x } \Delta T$

ΔL = 6.5 x 10-6 x 48" x 60

ΔL = .019

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 21-3

In Figure 21-2, 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 9,000lb 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.

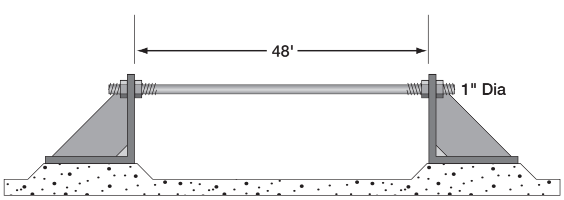


Figure 21-2.

21.2 Vessel Expansion/Contraction

Temperature fluctuations will cause weigh vessels to grow and contract. Figure 21-3 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: $\Delta L = X \text{ x } L \text{ x } \Delta T$

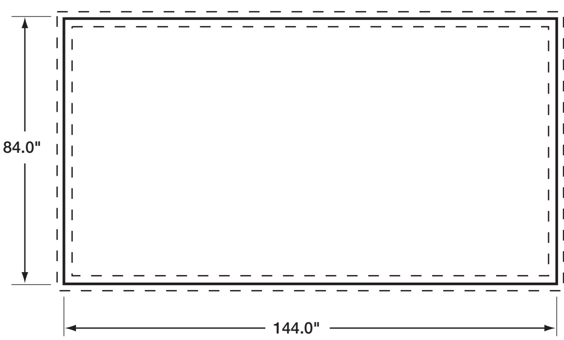


Figure 21-3.

If the vessel is made from mild steel, the length will vary by ± .028" (6.5 x 10-6 x 144 x 30), and the width will vary by ± .016" (6.5 x 10-6 x 84 x 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 Figure 21-4, the change in diameter (ΔD) resulting from a change in temperature (ΔT) is given by:

$\Delta D = a \text{ x } D \text{ x } \Delta T$

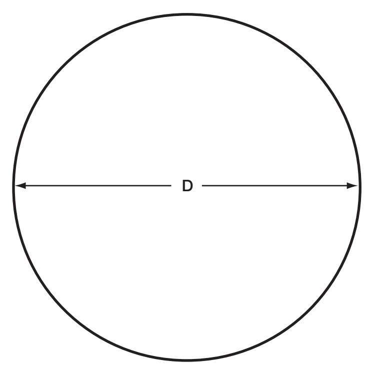


Figure 21-4.

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:

ΔD = 9.6 x 10-6 x 96 x 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 21-5. See **(Attaching Piping to Weigh Vessels)** in Section 20.0 on page 37 for detailed guidelines on this subject.

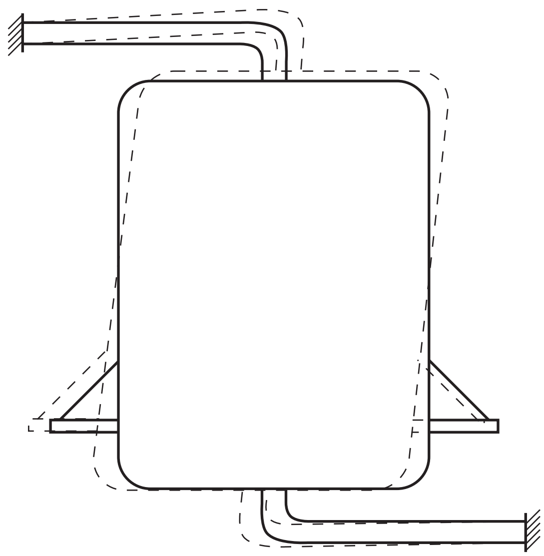


Figure 21-5.

22.0 Wind and Seismic Effects on Vessel Stability

22.1 Overview

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.

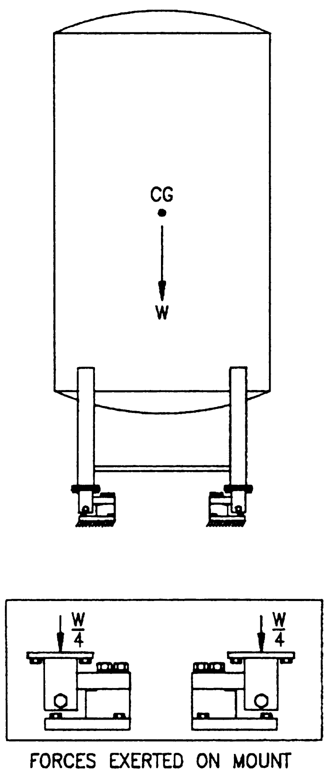


Figure 22-1.

In general, these forces act horizontally at the center of gravity (CG) of the weigh vessel. Figure 22-1illustrates 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 22-2 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} equaled 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.

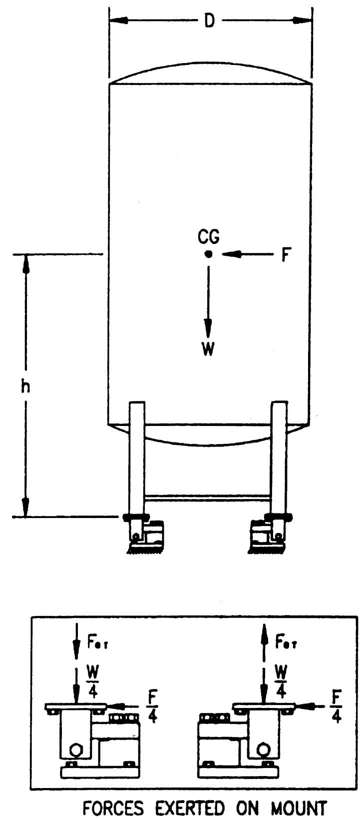


Figure 22-2.

The relationship between F_{0T} and F may be stated as follows for the vessel shown in Figure 22-2:

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 22-3 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.

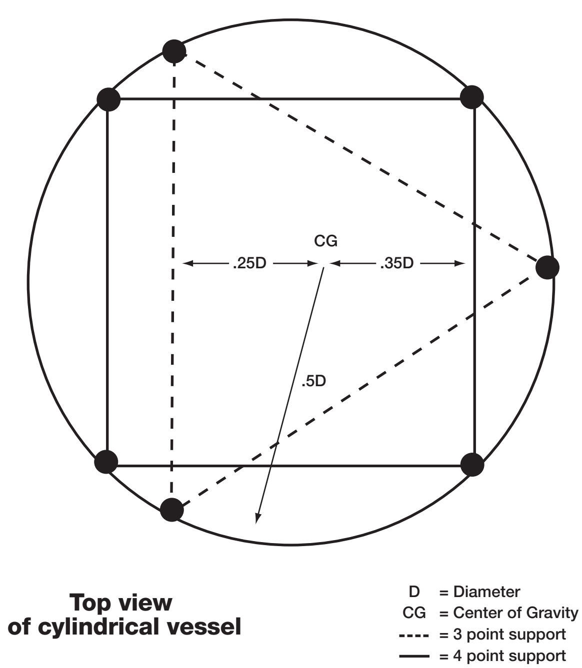


Figure 22-3.

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.

22.2 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 22-4 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.

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 22-5, 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.

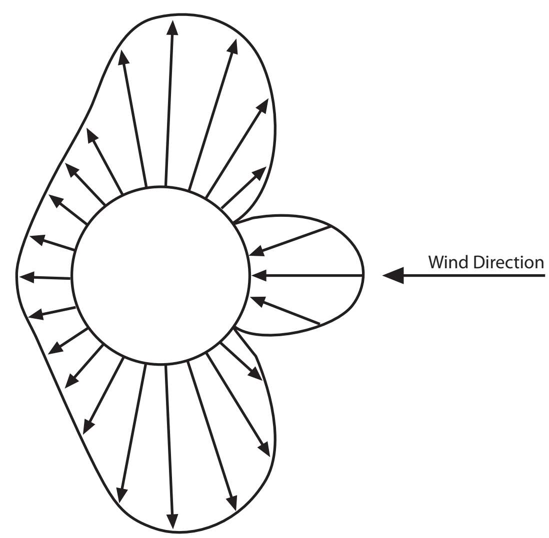


Figure 22-4.

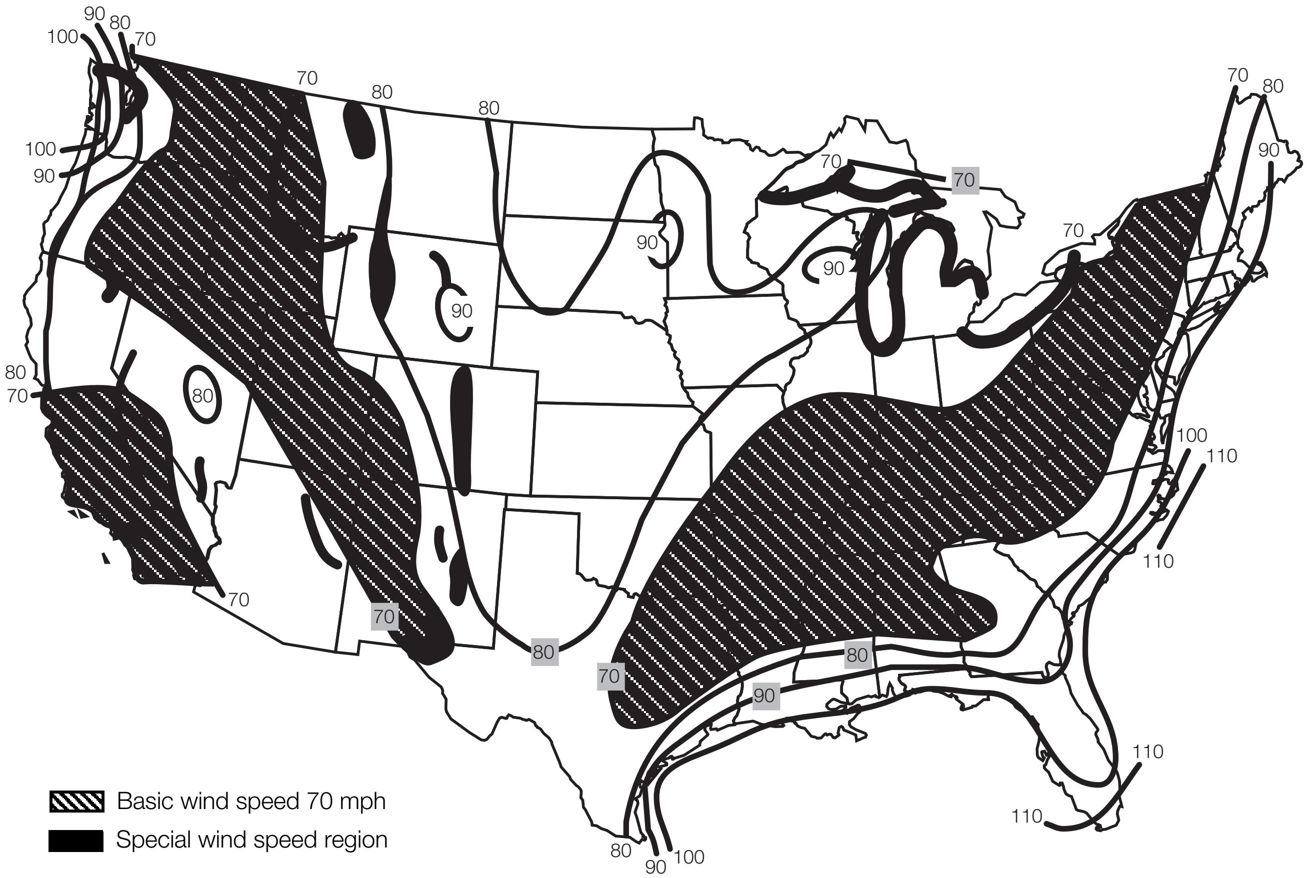


Figure 22-5.

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

22.3 Seismic Forces

Figure 22-6 on the next page 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 22-6) 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 :

- 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)?
- Contain sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released?
- Support the operation of public utility facilities?
- 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).

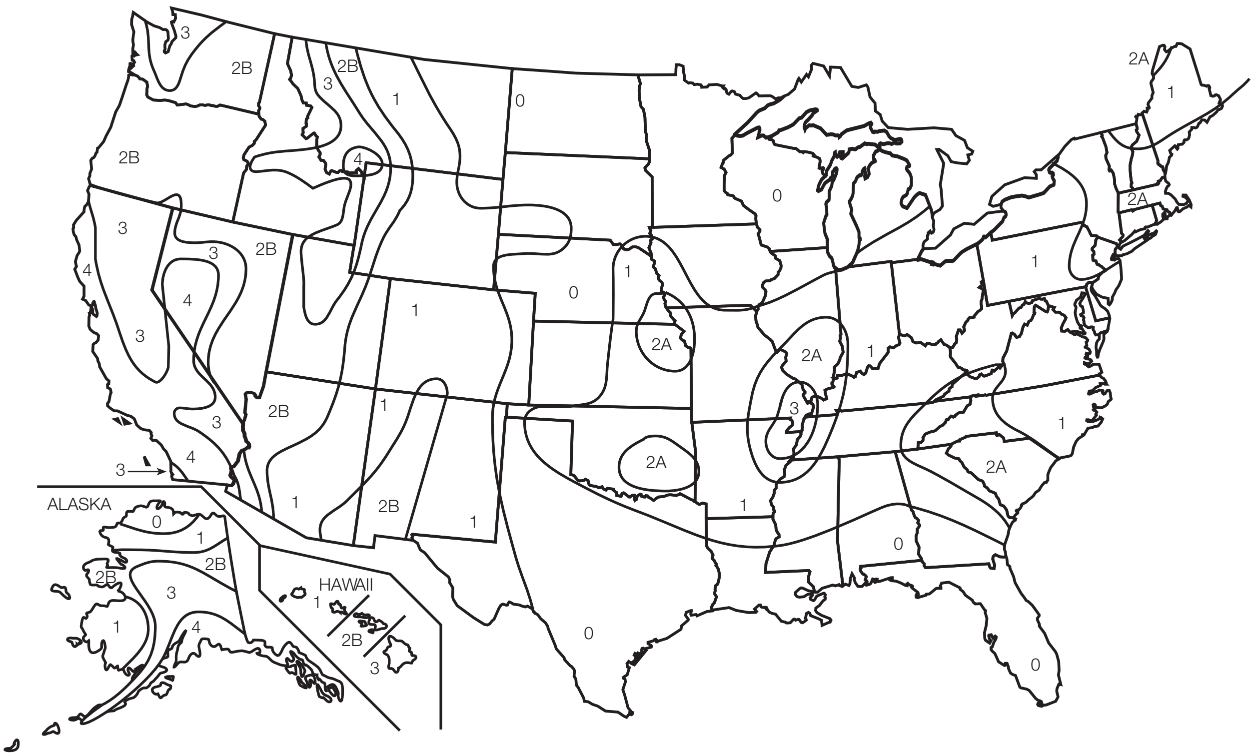


Figure 22-6.

23.0 Load Cell Terms

We know that a load cell is an electromechanical device. It can be called a transducer as it converts one form of energy to another—mechanical force or stress to electrical energy. A load cell has various characteristics that are measurable. These characteristics are determined by the type of metal used, shape of the load cell and how well it is protected from its environment. To understand load cells, there are terms that you need to become familiar with so you can better match the load cell to your application.

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

COMBINED ERROR - (Nonlinearity 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 measure on both increasing and decreasing loads.

CREEP - The change in load cell output occurring over time, while loaded, and with all environmental conditions and other variables remaining constant.

CREEP RECOVERY - The change in no load output, occurring with time, after removal of a load which had been applied for a specific period of time.

DRIFT - A random change in output under constant load conditions.

ECCENTRIC LOAD - Any load applied parallel to, but not concentric with, the primary axis.

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

EXCITATION - The voltage applied to the input terminals of a load cell. Most load cells have a rated excitation voltage of 10 VDC. There are load cells available that are rated at 15, 20 and 25 VDC and also some that have both AC and DC excitation ratings.

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. Hysteresis is measured as percentage of the full scale rated output (% F.S.). Common load cell hysteresis values are .02% F.S., .03% F.S. and .05% F.S.

INPUT BRIDGE RESISTANCE - The input resistance of the load cell. It is measured by placing an ohmmeter across the input or excitation leads. It is usually higher than the output bridge resistance because of the presence of compensating resistors in the excitation circuit.

INSULATION RESISTANCE - The DC resistance measured between the load cell circuit and the load cell structure.

NON-LINEARITY - The maximum deviation of the calibration curve from a straight line drawn between the no load and rated load outputs. It is expressed as a percentage of the full-scale rated output. It is measured on an increasing load only. Common non-linearity values are .02% F.S. and .03% F.S.

OUTPUT - The signal produced by the load cell where the output is directly proportional to excitation and the load applied. The signal must be in terms such as millivolts per volt (mV/V) or volts per ampere (V/A).

OUTPUT BRIDGE RESISTANCE - The output resistance of the cell. It is measured by placing an ohmmeter between the signal or output leads. Common bridge resistances are 350Ω, 480Ω, 700Ω, 750Ω and 1000Ω.

OUTPUT, RATED - The algebraic difference between the output at no load and the output at rated load.

REPEATABILITY - The maximum difference between load cell output readings for repeated loadings under identical loading and environmental conditions.

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

SAFE OVERLOAD RATING - The maximum load, in percent of rated capacity, which can be applied without producing a permanent shift in performance characteristics beyond those specified. A common safe overload rating is 150% F.S.

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

SHOCK LOAD - A sudden increase in load usually caused by dropping weight onto the scale. Can cause permanent load cell damage.

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

TEMPERATURE EFFECT ON RATED OUTPUT - The change in rated output due to a change in ambient temperature. It is 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. It is 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 temperature over which the load cell is compensated to maintain rated output and zero balance within specified limits.

ULTIMATE OVERLOAD RATING - The maximum load, in percent of rated capacity, which can be applied to a load cell, without producing a structural failure.

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

Figure 23-1 may help you understand important load cell terms.

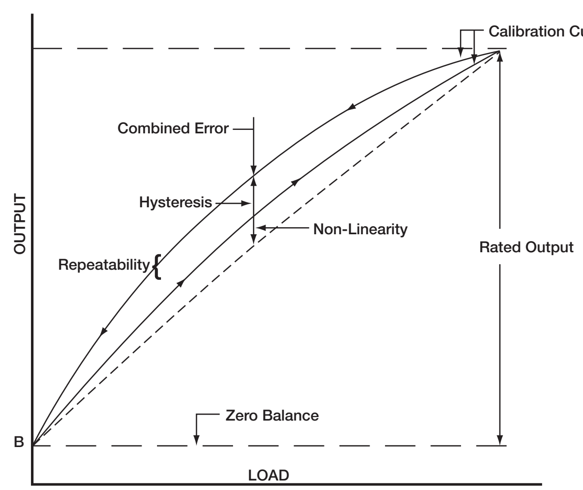


Figure 23-1.

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