



Structural Design of Tank Weighing Systems

1. Initial Observations

Some essential rules must be followed when installing load cells in tanks. For example, tanks are frequently subject to weather conditions or effects related to production. When new upright tanks are erected outside (silos, coal hoppers, etc.), applicable building regulations must be observed for the relevant structures. Note that subsequently installed weighing devices may also be considered as "significant changes" in terms of building regulations. The advice of a structural engineer is recommended in these cases. Building regulations generally cite the "state of the art" in terms of safety considerations. For example, wind loads are covered by DIN 1055 Part 4, "Load assumptions for structural components."

The project engineer for a tank layout should also be informed about any special company-specific rules. Tanks must frequently be secured so they cannot be picked up, even in areas covered by a roof, if the contents are hazardous and forklift trucks are in operation around the storage area.

2. Load Distribution

An optimum arrangement of load cells for determining the weight of tanks is achieved when the tank rests on three bearing points and a load cell is positioned on each support. This state is referred to as *statically determinate*. The overall load should also be distributed as evenly as possible over the three load cells. In the case of upright or suspended cylindrical tanks, the best way to meet this requirement is if the three load cells are arranged at equal distances from the vertical axis of the tank and are offset from each other by 120° on the same plane. Figure 1 defines the arrangement of bearing points for horizontal tanks.

If not all the supports in a system are equipped with load cells, an uneven distribution of the support load is recommended. The supports with load cells should have greater loads than the supports without load cells. Following this guideline can improve the overall accuracy of the weighing device. When designing the system and selecting the load cells, it is preferable for all the load cells to be subject to loads of the same magnitude.

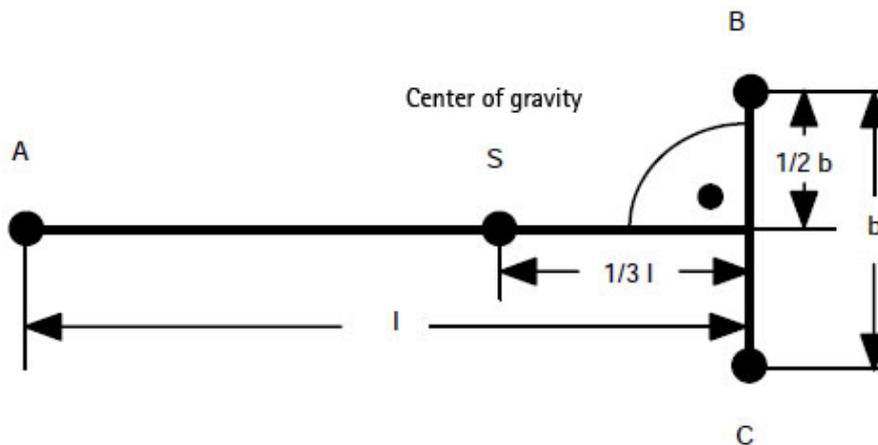


Figure 1: Arrangement of bearing points A, B and C for a horizontal tank

If a tank is supported on four or more points, the bearing of the tank is *statically redundant*. Load cells must be installed at all the bearing points in these cases. An even distribution of the load on the individual transducers can only be achieved during assembly. The transducer loads must be measured individually for this purpose. Then, if there are impermissible differences, the height of the relevant load cells must be changed (with compensating shims, etc.). Load cells with loads that are too low are generally positioned diagonally from each other.

3. Center of Gravity of a Tank

Ideally, the center of gravity of a filled tank should not be any higher than the bearing points of the tank – a feature that is frequently not implemented.

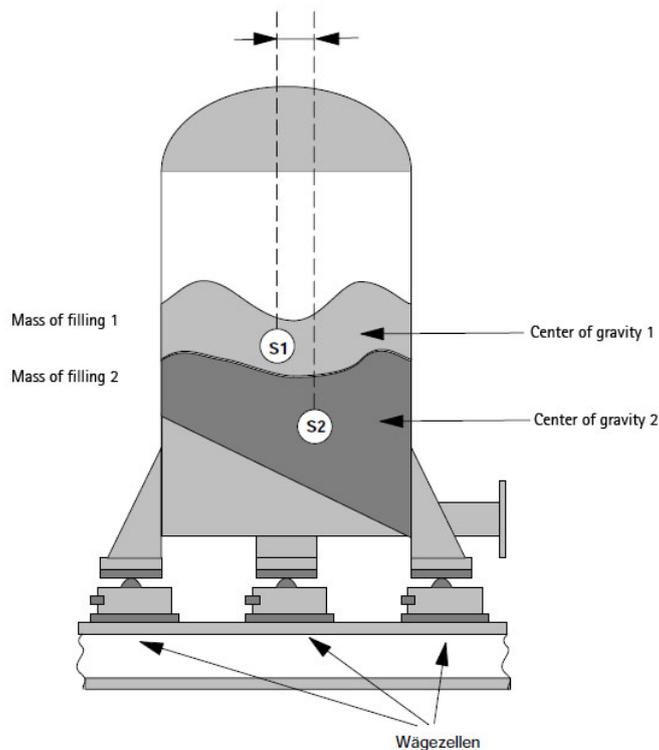


Figure 2: Distribution of the center of gravity of a tank with an inclined discharge base depending on the mass of filling

For reasons of stability it is advantageous for the center of gravity to be lower than the bearing points. The position of the center of gravity as a function of the filling level has a considerable effect on the number of load cells that are used. If the filling is arranged symmetrically to the load cells, it may be possible to set up a weighing device with one load cell, since the position of the center of gravity moves along a vertical line (see also 6.3). If the center of gravity also moves to the side as the mass of filling changes, all the supports must be equipped with load cells. Rocker and fixed bearings should never be considered for applications of this type!

Figure 2 illustrates the necessity of using load cells on all bearing points if the position of the center of gravity changes.

4. Supply Connections on Tanks

Tanks frequently require supply connections, for example, to supply and discharge contents and for the electrical, hydraulic or pneumatic supply of additional units mounted on the tank.

These supply connections can lead to force shunts, which manifest themselves as errors that affect the measuring accuracy of the weighing device. Supply connections must be flexible in the vertical direction. Figures 3 to 7 show some examples of suitable designs for supply connections. In any case, these aspects should always be taken into consideration for financial reasons in the design and planning phase. If rigid pipes without a flexible link are used, the tank should preferably be connected with the longest possible horizontal pipe section. The pipe section should also have expansion compensation in the longitudinal direction (Figure 3).

The horizontal section of pipe has a spring effect in the vertical direction, which becomes more yielding as the length increases. The mechanical force exerted by the pipe in the form of a pseudo load (tensile or compressive) on the load cells becomes correspondingly small and is no longer relevant for measuring accuracy.

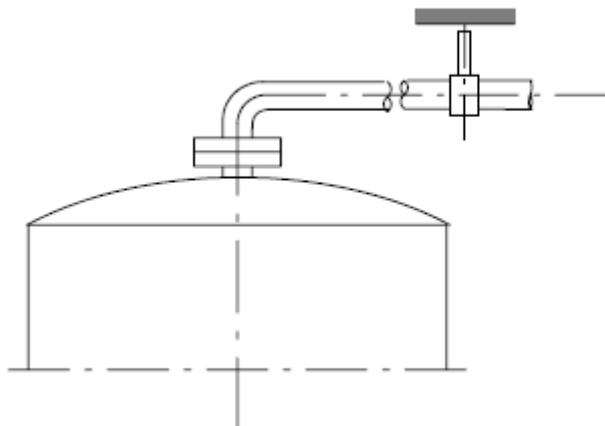


Figure 3: Long horizontal pipe connection

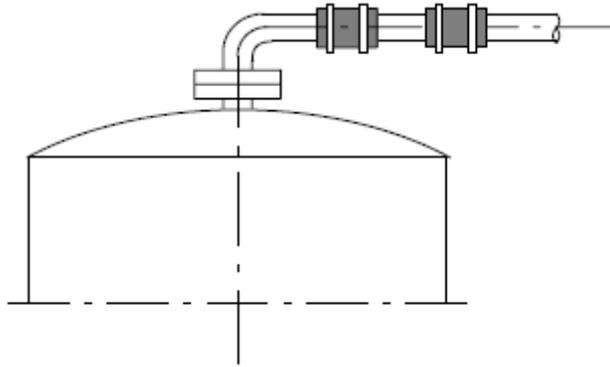


Figure 4: Elastic pipe coupling

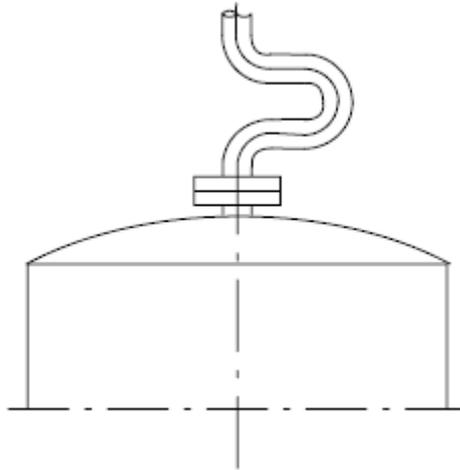


Figure 5: Pipe elbow

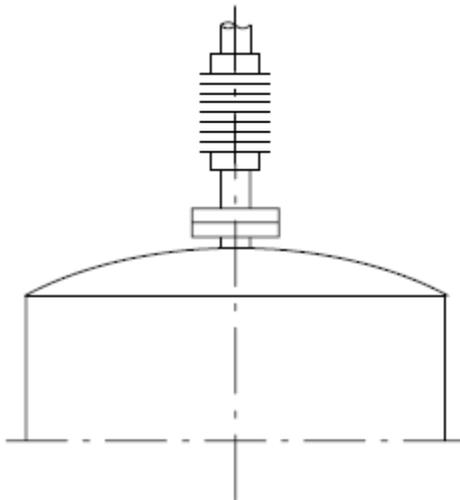


Figure 6: Mechanical compensator

Several pliable couplings can also be used instead of a layout with one long pipe (Figure 4). Good results in terms of preventing force shunts are obtained with hose connections made of readily malleable elastic materials. In this case, the compatibility of the elastic materials with the filling and/or cleaning materials must be checked (in the food industry or pharmaceutical technology, for example). Another possibility for reducing undesirable force shunts caused by connecting pipes is using a layout with a pipe elbow (Figure 5).

In cases where a vertical pipe supply is required (i.e., in the direction of the gravitational force to be measured) or hose connections cannot be used, pipe connections with compensators (such as metal bellows) have proven effective (Figure 6). Strict installation tolerances must be observed when installing these compensators. If a second set of metal bellows is used and connected with the first by a section of pipe, it is possible to compensate for greater tolerances. Metal bellows are not permitted in some cleaning-intensive areas of the food industry.

The connecting branch shown in Figure 7 represents the best solution in terms of reducing force shunts. An open connecting branch prevents contact between the pipe and the tank. This form cannot be used in closed systems, such as in pressure tanks.

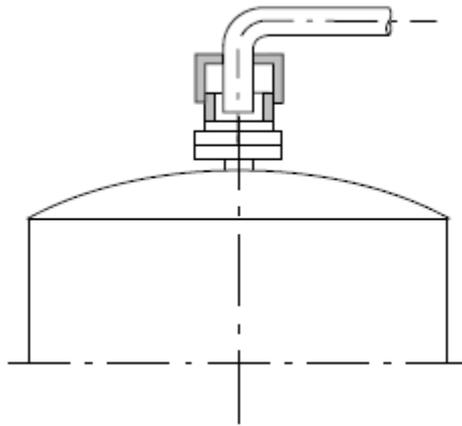


Figure 7: Open filling stud

It should always be noted that the material in the connecting lines is included as part of the weight. The filling level of the supply and discharge lines that are directly connected with the tank should therefore be reproducible when the weight is measured. This means the lines should be either always empty or always full when measurements are taken.

5. Pressurized Tanks

In closed plants, the pressure in the system can affect the weighing results. Especially in the chemical industry, high positive pressures are required for some processes. On the other hand, extraction plants for weighing powdered material generate negative pressures of 100–300 mbar. If the piping is connected to the tank vertically, as shown in Figures 5 and 6, a force is exerted that directly affects the measurement results. The effect is equivalent to the product of the force multiplied by the cross-sectional area of the piping. If pressure conditions during the weighing process are constant, this amount can be taken into consideration (calculated) in the measurement. A horizontal pipe layout is more suitable and preferable to a vertical pipe connection in every case. In this case, the parasitic forces that arise are absorbed by the installation supports.

6. Examples of Designs for Arranging and Installing Load Cells

Typical tank designs are represented in a stylized manner by way of example. Design details and references to problems are presented in greater detail in the relevant sections.

6.1 Upright Tanks

Installation with two fixed supports and one load cell is possible for weighing liquids and bulk goods in tanks with central filling. To provide the appropriate level of accuracy, the tank must have a symmetrical layout. The product weight must be spread evenly across the tank or hopper in order to receive the proper results and maintain the accuracy required. In all other cases, especially if greater degree of accuracy is required, an installation with preferably three or, in some circumstances, more load cells is necessary.

6.1.1 Rigid Installation of a Load Cell

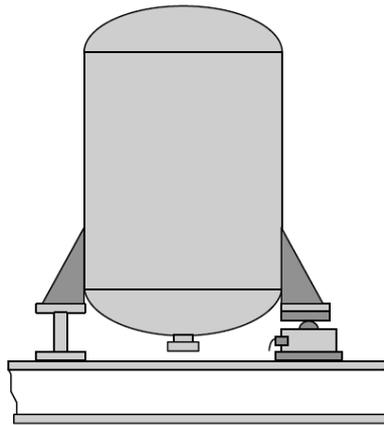


Figure 8: Upright tank in rigid installation with one load cell

This simple design on a carrier with a rigidly installed load cell is not recommended. The design alone results in problematic effects on the load cell. Due to deformations as the filling level changes, as well as vibrations and changes in temperature, effects on the load cells generally cannot be ruled out. Nevertheless, a few cases of this design may be found.

6.1.2 Upright Tank with Two Fixed Bearings and One Load Cell with Compensation

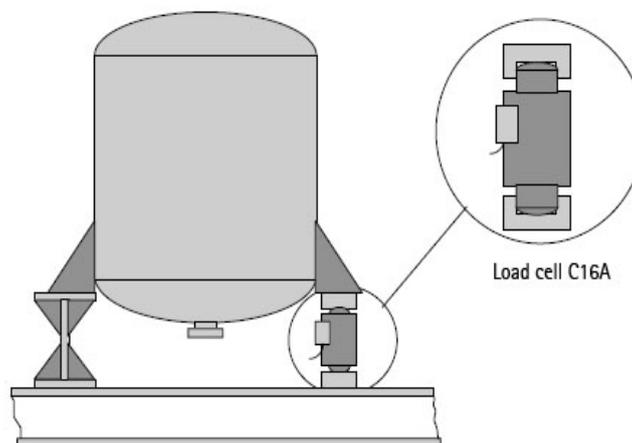


Figure 9: Upright tank with two fixed bearings and one load cell with compensation

This filling level measurement uses a load cell arranged in a cradle with two fixed bearings, which also serve to restrain horizontal movement of the tank. This cost-effective design keeps the load cell free of unacceptable effects.

6.1.3 High Round Silo on Three or Four Load Cells

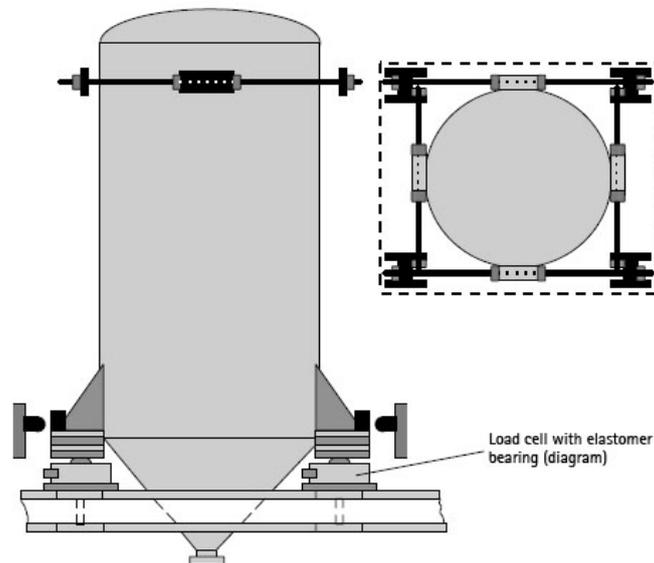


Figure 10: High round silo

Exact levels are usually measured on three load cells. Although arrangements with four load cells are sometimes found in rectangular symmetrical designs, this arrangement is generally not favored due to its static redundancy and higher price. On the other hand, they are easier to install in the structure. Self-centering elastomer bearings do not require any stay rods. They are usually combined with fixed stops instead. Additional stay rod guides are needed in the upper area for very high tanks. In the example in Figure 10, they are designed as stay rods with loose initial stress and locking. Fixed stops would continuously come in contact with the tank at this point whenever it unavoidably moved slightly out of its ideal position and the contact friction would lead to force shunts. Roller stops or cable guides are less frequently used alternatives.

6.1.4 Round Silo on Three Weighing Modules

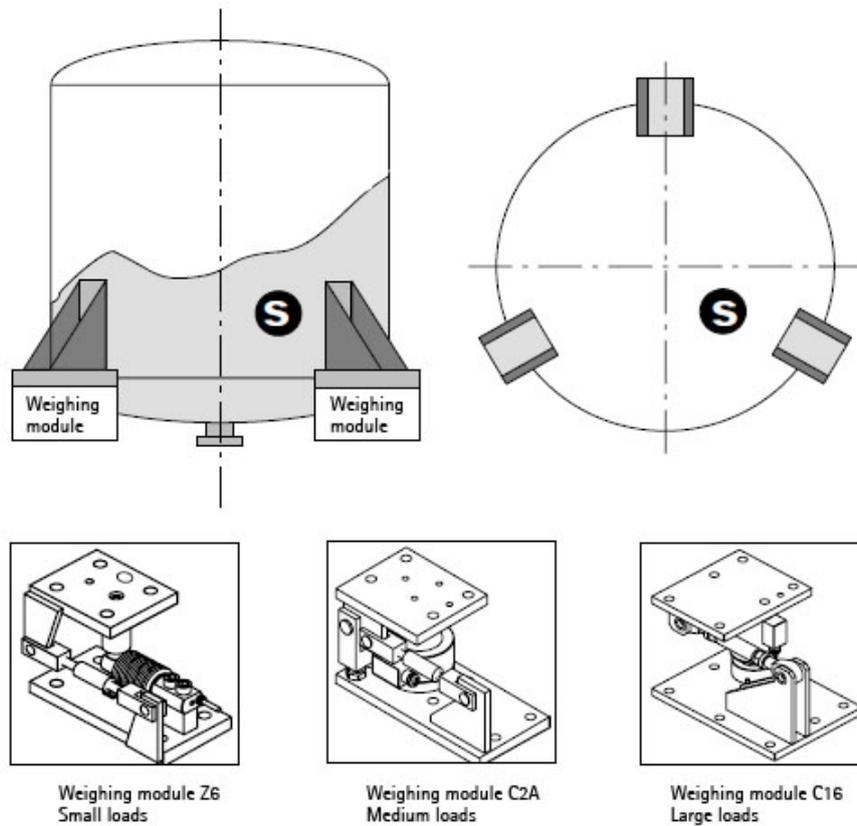


Figure 11: Round silo on weighing modules

Three weighing modules with integrated stay rods that contact the circumference of the structure tangentially will hold the tank horizontally stable with no need for any additional measures. The anti-liftoff device, also located in the weighing module, prevents the tank from tipping over. This eliminates several structural details in the outer construction. Typical weighing modules for lower, medium and higher loads are also illustrated here by way of example. These standardized elements simplify design and save considerably on construction expenses. On the other hand, the design requires considerable care and overhead to ensure that contact surfaces are parallel, heights are aligned, etc.

6.1.5 Flanged Tanks on Weighing Modules

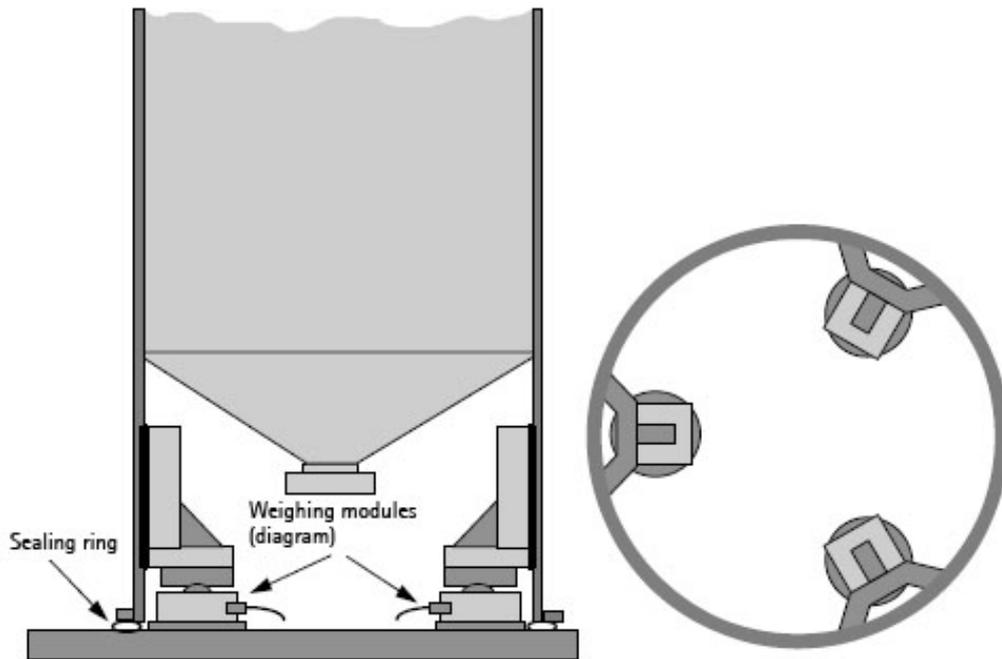


Figure 12: Arrangement of weighing modules for a flanged tank

Flanged tanks, which are used quite frequently in practical applications, have an outer casing that extends to the base and serves to ensure the overall stability of the arrangement. Installation on load cells is not a simple matter. Figure 12 shows a design variant for weighing these tanks with load cells. This suggestion is also relatively easy to implement in existing systems. Braces are mounted or welded into the inside wall of the tank. The load is inserted rigidly into the load cell. Load cell weighing modules should preferably be used in this case as well, because they contain an anti-liftoff device, etc. (not shown in Figure 12 to enhance clarity). Raising the structure even slightly is enough to direct the entire weight force into the load cells. The system must be sealed frequently. This is achieved through a circular sealing ring that does not cause any force shunts due to its flexibility.

6.1.6 Rectangular Hopper in a Filling Station on Four Load Cells

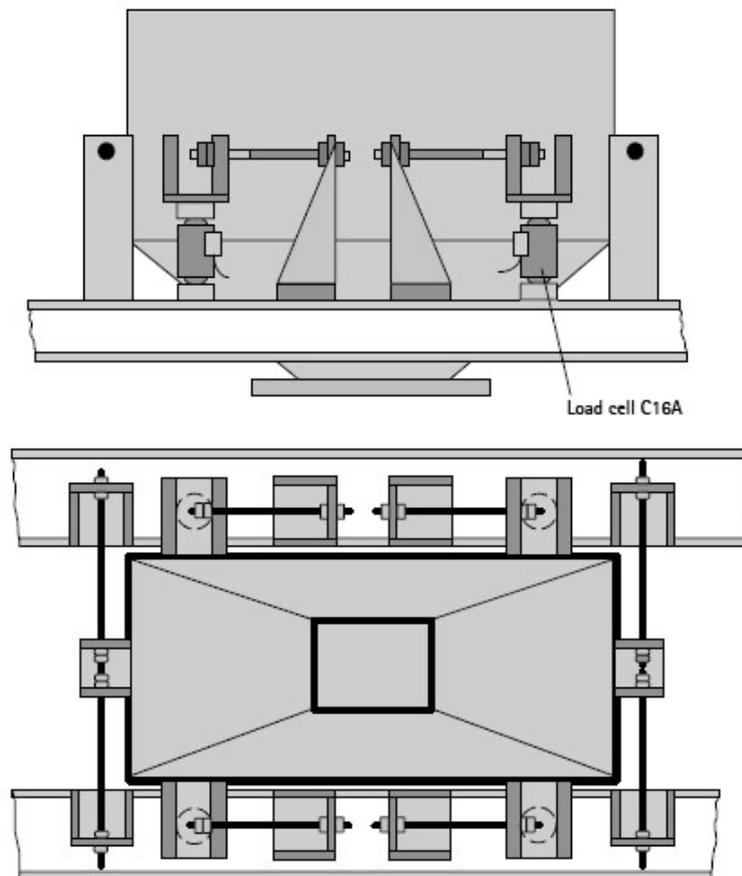


Figure 13: Rectangular hopper on four load cells

Harsh environments or unusual mechanical effects can affect the quality of your measurements. For example, severe vibrations due to shaker devices or mixers, the influence of a bulky or heavy product being added to the vessel, or the discharge of the contents in controlled amounts. In addition, there are temperature effects which can cause the structure to expand and contract as the temperature changes throughout the production process. All of these real-time mechanical influences will twist and torque the load cells in multiple directions which results in non-reliable measurements or poor accuracy. In these situations, it is recommended to have additional support points and load cell modification which will ensure you do not lose any measurement integrity but rather add stability to your structure. This in the long term will result in reliable and accurate measurements in the end product, which will keep your customers happy.

Many times it is recommended to place a stay rod or a sway bar built into the structure or as an additional support point attached to the structure.

Load cells with elastomer bearings or installed in a vertical position like those in the example of pendulum load cells (see section 6.3) can also benefit from these support devices. Ask your HBM Applications Engineer for assistance in the strategic placement of these support points.

6.2 Suspended Tanks

Centering problems can often be eliminated or simplified on suspended tanks with simple, pliable, round tie rods. In addition to providing protection against tipping, which is always necessary, stay rods are needed to prevent oscillating and turning.

6.2.1 Suspension on Two or Three Load Cells

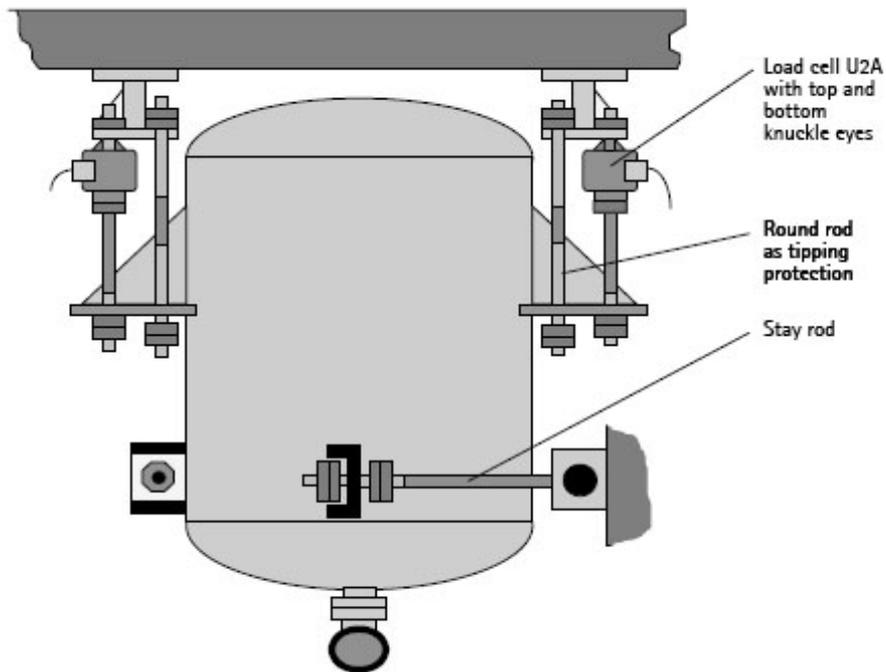


Figure 14: Suspended tank on three load cells

The overall simple design requires several tangentially arranged stay rods. In cases with reduced stress, their functions can be assumed by a lower side pipe outlet.

6.2.2 Centric Suspension on One Load Cell

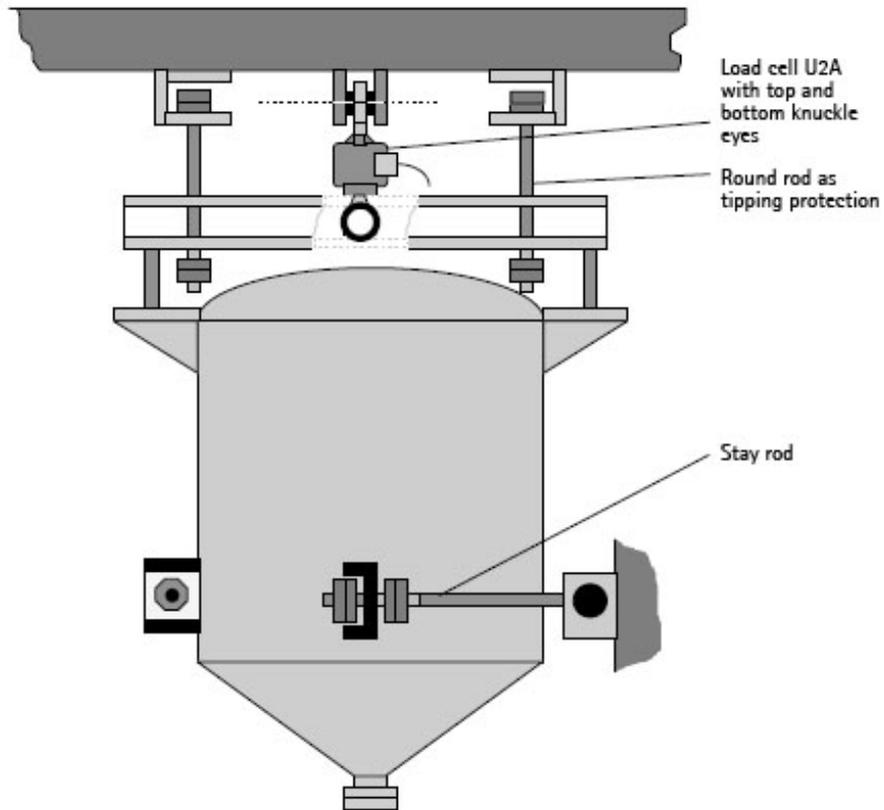


Figure 15: Suspended tank on one load cell

A special restraint is essential in this arrangement to prevent oscillating and turning.

6.3 Horizontal Tanks for Liquids

Horizontal tanks for liquids usually fulfill the condition that the center of gravity of the content must move approximately along a vertical line as the mass of filling changes. An arrangement with one load cell under one tank bracket and two fixed bearings under the other tank bracket is therefore sufficient for relatively simple level measurements. The idealized tank rests with half its weight on one self-centering pendulum load cell and on two fixed bearings. No further restraint is required under normal circumstances. In the case of very long tanks, however, for additional protection against tipping over due to lateral impacts on the tank, fixed stops can be provided to limit lateral movements at both ends of the tank cradle that is resting on the load cell.

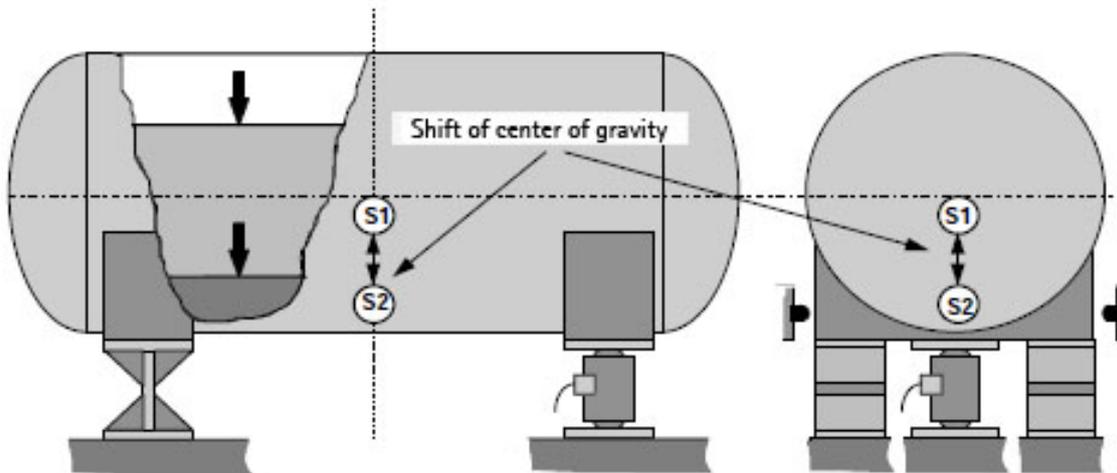


Figure 16: Horizontal tank for liquids with a C16 load cell (diagram)

In practical applications, however, the distribution symmetry of the contents is often disturbed by a slight, deliberate inclination of the base line to one side and the outlet that is located there. A self-centering arrangement of three load cells is the optimum solution for more exact weighing, with fixed stops as the best way to implement horizontal restraints.

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Email: info@hbm.com

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