CHAPTER 6

TANK AND BATCH WEIGHING

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6.0 OVERVIEW OF ELECTRONIC WEIGH SYSTEMS

6.1 INTRODUCTION

In this chapter on Tank and Batch Weighing, we have used examples, and refer to, the Electronic Sensing Device, the Load Cell or Transducer. The principles remain, even though sensing devices other than the Load Cell are substituted.

In its simplest form, a weigh system consists of a vessel whose contents are to be monitored, load-sensitive transducers that generate a signal proportional to the vessel weight, and an electronic device to power, amplify, interpret and display the signal. However, the accuracy of such a system, while a function of the transducers and instrumentation, is dependent upon the vessel, design, support structure, piping attachments, lateral restraint system, vessel environment (temperature, traffic, nearby equipment), and proper selection of transducer accessories. In short, weigh system accuracy is tied to the degree of attention given to the mechanical details.

6.2 HIGH ACCURACY WEIGH SYSTEMS

High accuracy weigh systems exhibit system errors under 0.05% for buy-and-sell to 0.25%. To achieve this, the mechanical requirements are as follows:

1. The weigh vessel must be fully supported by transducers. With load cells, the number may vary from one (in tension) to eight (in compression). Generally, as the number of load cells decreases, the vessel wall thickness and support structure stiffness must increase to carry the higher vessel support reactions.

2. Precision load transducers with full temperature compensation must be used.

3. Mechanical restrictions from attached piping and lateral restraints should be avoided. Highly flexible piping attachments are recommended.

4. Hot gas or steam-heating schemes which produce variable buoyancy should be avoided. Use hot oil or water instead.

5. Pressurized or vacuum vessels also produce variable buoyancy. This effect can be electrically compensated by wiring a pressure transducer into the load cell circuit.

6.3 LOW ACCURACY WEIGH SYSTEMS

Low accuracy weigh systems are those with a system error greater than 0.5%. Mechanical considerations are relaxed considerably.

1. The weigh vessel need only be supported partially by load transducers, usually one or two on any side of the vessel. This requires that the contents be self-levelling and the vessel itself be without partitions. The load function carried by the transducers should not change. When these two requirements are not met, the vessel should be supported fully, regardless of the accuracy required.

2. Modest mechanical restrictions may be tolerated, but nonlinear mechanical hangups, or frictional interfaces, must be avoided.

3. General purpose transducers are satisfactory for these systems.

See Figure 6.1 for Vessels at Constant Ambient Temperature Indoors and Figure 6.2 for Heated Vessels at Ambient Temperature Outdoors, on the following page.

A horizontal tank supported by four load cells yields a high accuracy weigh system independent of material location. A lower accuracy system suitable for unpartitioned vessels with self-levelling materials requires only two cells. See Figure 6.3 for illustrated Horizontal Tanks in Compression on the following page.

Lengths of Tension Flexure Rods are sized to accommodate radial thermal expansion. See Figure 6.4, Vertical Tanks in Tension on the following pages.

6.4 ACCURACY VS. REPEATABILITY

System accuracy should not be confused with repeatability. As long as the mechanical error in a given system is linear with deflection and independent of the environment (e.g., temperature, traffic, surrounding vessels), the inherent system repeatability will be greater than its accuracy. For example, instrumentation may have an overall accuracy specification of 0.01% of reading $\pm$ 1 count, of which

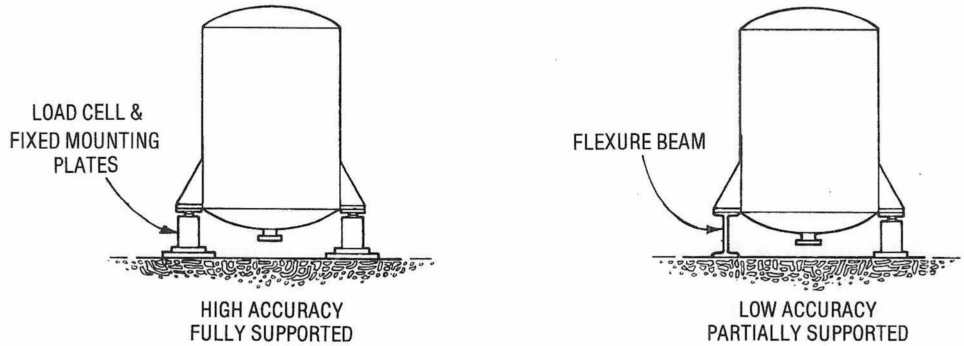

Figure 6.1. Vessels at Constant Ambient Temperature Indoors

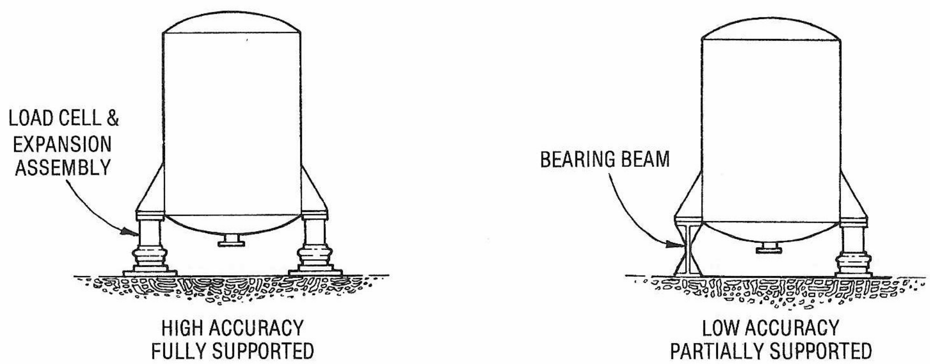

Figure 6.2. Heated Vessels at Ambient Temperature Outdoors

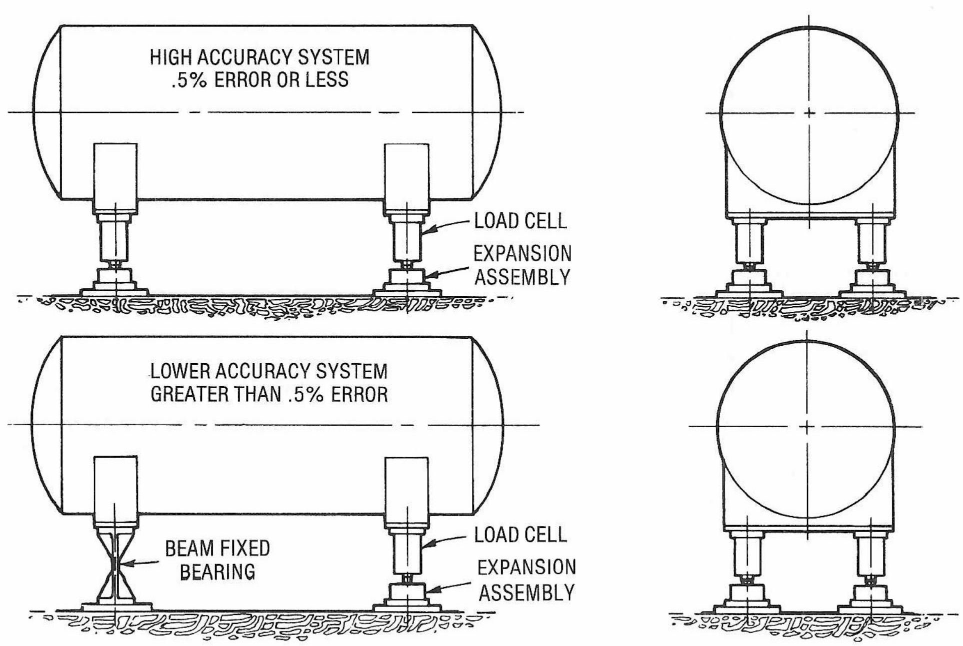

Figure 6.3. Horizontal Tanks in Compression

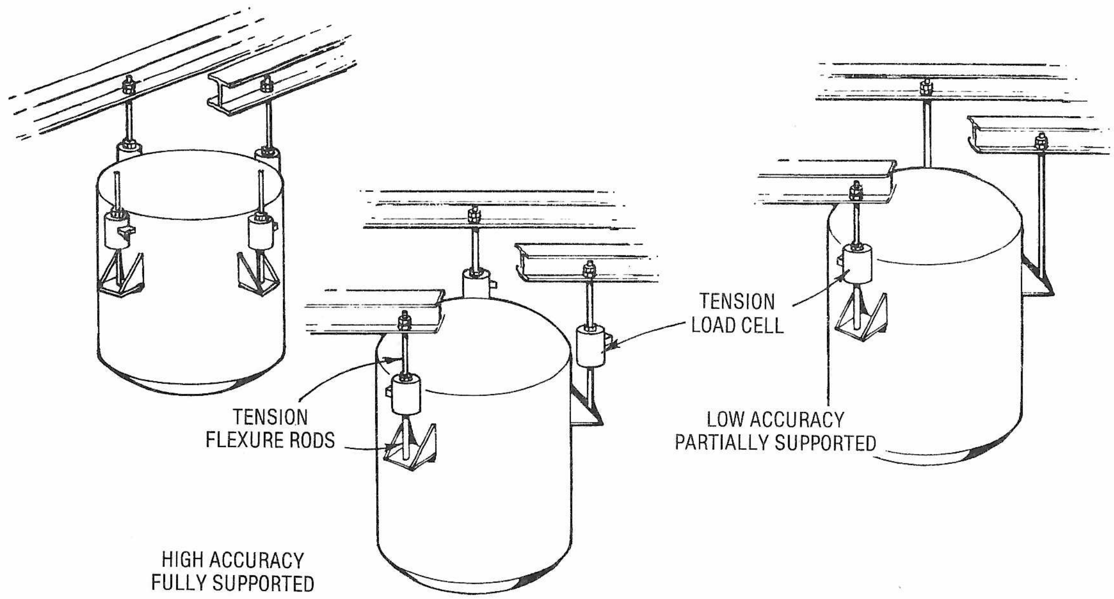

Figure 6.4. Vertical Tanks in Tension

repeatability is but a small fraction. Load cells, meanwhile, typically display a repeatability of 0.1 to 0.2%. Thus, most systems will be repeatable within 0.03% of full scale, independent of how the system is calibrated.

For most batching operations, repeatability is essential, whereas accuracy (actual pounds used) is of secondary importance once the operating parameters have been established. Field calibration, when required, is generally done by electronic substitution.

For buy-and-sell installations, where distribution is by weight, calibration and repeatability are essential. Field calibration is performed employing a dead weight method.

6.5 DEFINITIONS

ACCURACY - Ability of the system to perform weighing functions within an acceptable or desirable tolerance. This is stated as a percentage of either full scale or reading, or $\pm$n count(s) in reference to the total number of scale divisions.

REPEATABILITY - The ability of the system to read the same value when the measured weight is applied repeatedly, in the same manner with the same quantity, under constant conditions.

See Figure 6.5 for Readout Accuracy.

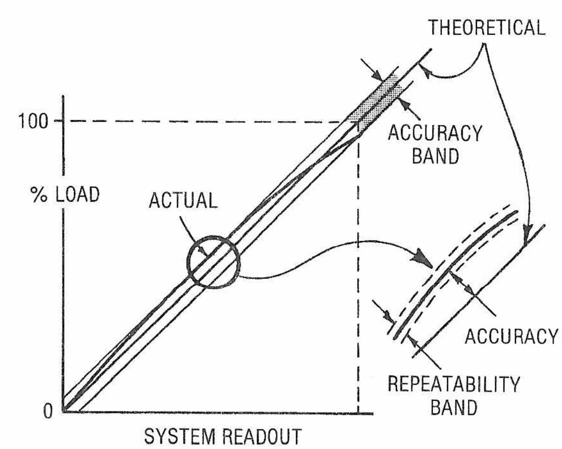

Figure 6.5. Readout Accuracy

6.6 VESSEL MOUNTING/TENSION OR COMPRESSION

Either method routinely yields high accuracy weigh systems and, except for the few observations which follow, there is little to recommend one over the other. Tension systems have the edge in mechanical simplicity. In most cases, plant layout is the determining factor.

6.7 MAXIMUM WEIGH SYSTEM ACCURACY AND STABILITY

Maximum weigh system accuracy and stability will be obtained when the vessel is mounted in compression on a rigid concrete foundation. This arrangement avoids the usual sources of deflection, variations in load cell alignment, and vibration that acts to compromise calibration accuracy and operational stability. Therefore, when extreme accuracy is required (<0.05%), this approach should be considered first.

6.8 VESSELS WEIGHING UP TO 3,000 POUNDS

Vessels weighing up to 3,000 pounds are candidates for the simplest system; a single load cell in tension. Lateral restraints may be added if required to keep vessel from tilting, swaying and rotating.

6.9 WEAK FLOOR OR NO FLOOR

When upgrading an older plant, the weigh vessel may require a special installation. A convenient floor may exist, but be too weak to carry the added weight, or there may be no convenient structure. See Figure 6.6, Special Installations; Older Plants.

6.10 ACCESS FOR INSEPECTION

When processes must be monitored via vessel viewports, arrangements must be such that the observer does not load the vessel. See Figure 6.7, Access for Inspection.

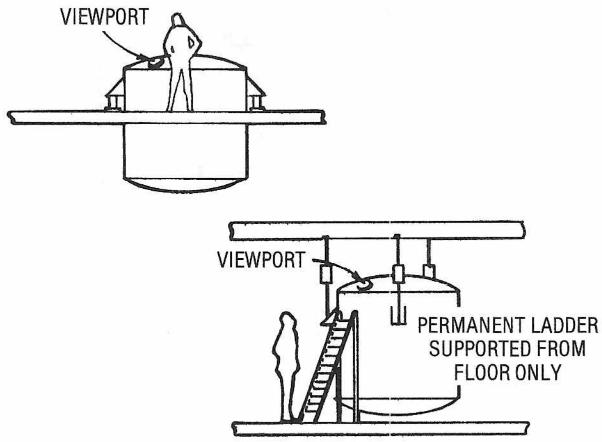

Figure 6.7. Access for Inspection

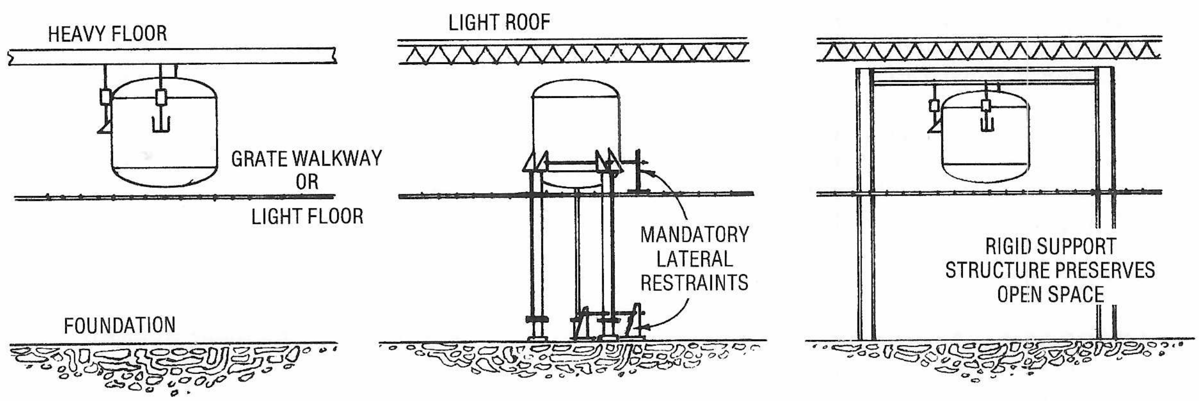

Figure 6.6. Special Installation; Older Plants

On the following page is Table 6.1, Other Considerations/Vessel Mounting/Tension or Compression, which is a breakdown of the Design Factors, Compression Mountings, and Tension Mountings.

TABLE 6.1

OTHER CONSIDERATIONS/VESSEL MOUNTING/TENSION OR COMPRESSION		
DESIGN FACTOR	COMPRESSION MOUNTING	TENSION MOUNTING
Weight Limit	Unlimited, as long as the number of vessel supports does not exceed eight; load distribution among the supports becomes difficult thereafter.	Usually designed to 10,000-20,000 gross weight since the structural reinforcement required for higher values becomes expensive. However, installations to 50,000 pounds per support (200,000 pounds gross) have been installed.
Load Cell Alignment	Cell alignment may vary during service due to overload floor deflection, local support beam twist, or vessel deformation. This may cause small calibration errors.	Cell alignment is unlikely to vary significantly in service since the tension flexure rods, and spherical washers, tend to accommodate local support deflections.
Vessels not at Constant Ambient Temperature	Low friction expansion assemblies are required to accommodate differential thermal expansion or contraction between the vessel and its support structure. Thermal insulation pads minimize heat conduction to load cells.	Differential motion between the vessel and its support structure is accommodated by adjusting the length of the tension flexure rods. Additional accessories are not required; the small sideload error introduced by friction in the expansion assemblies is avoided.
Lateral Restraints	Almost always necessary except when the vessel is at ambient temperature and in an isolated area, totally undisturbed.	May not be required for vented systems weighing nonhazardous dry products, free from structural vibration, since a hanging mass is inherently stable.
Sensitivity to Structural Support Vibration	A function of the stiffness of the structure and vessel support structures.	Tends to be more sensitive. This is due to reduced structural stiffness, damping capability caused by the tension linkage, and the likelihood of the vessel's having a small mass more readily set in motion.

6.11 FLOOR VIBRATION OR DEFLECTION

Avoid mounting a vessel to support structure subject or vibration from traffic or rotating equipment. See Figure 6.8.

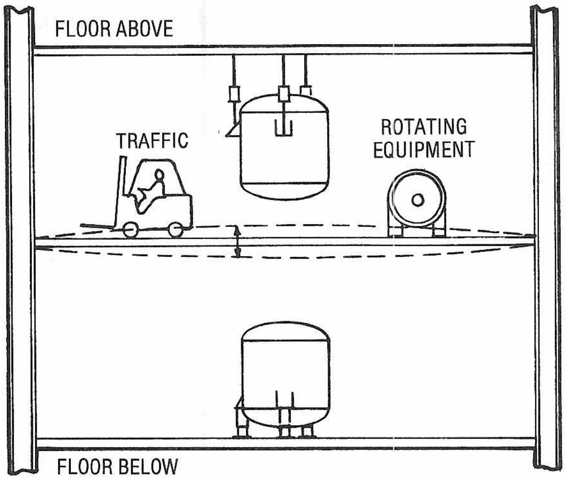

Figure 6.8. Floor Vibration or Deflection

6.12 LATERAL RESTRAINT INSTALLATION

If a weigh vessel requires some form of lateral restraints, consider which mounting configuration best accommodates the installation. See Figure 6.9.

6.13 OUTDOOR LOCATION

Vessels situated outdoors are mounted, usually, in compression on a concrete slab to minimize construction costs and maximize vessel stability. When material is to be transferred directly from the vessels to trucks or railroad cars, the vessels are sometimes

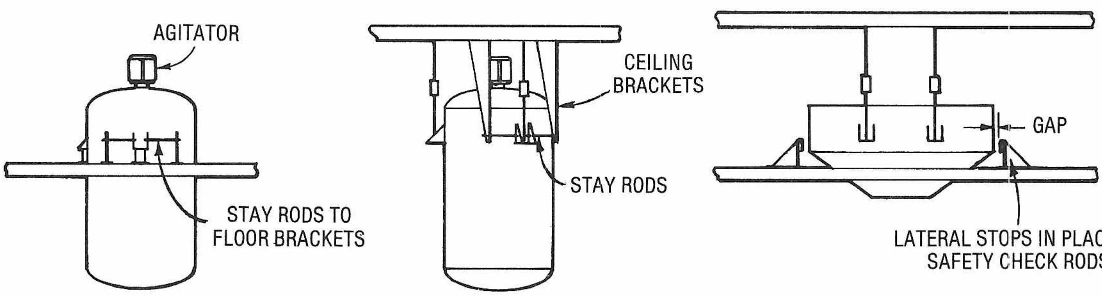

Figure 6.9. Lateral Restraint Installation

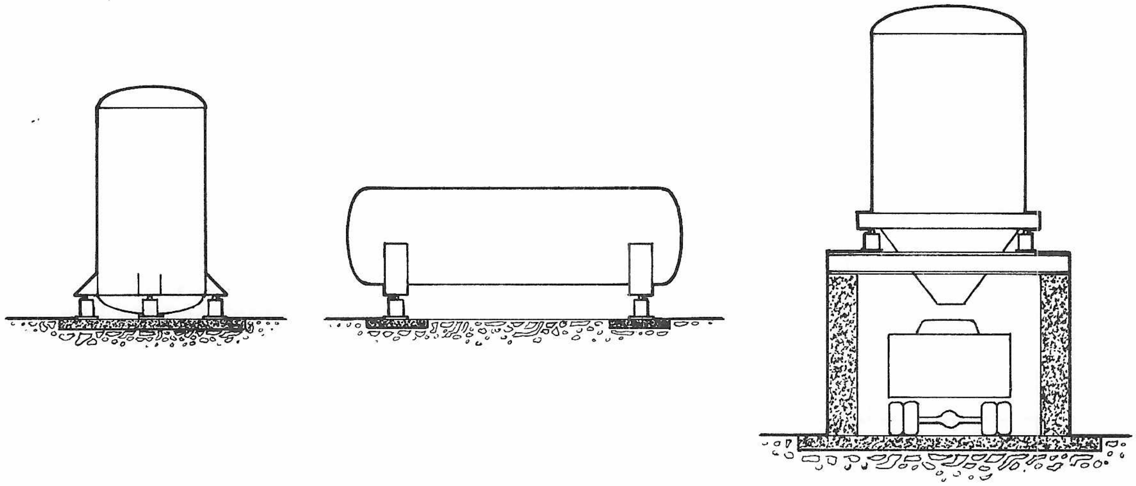

Figure 6.10. Outdoor Location

elevated by a steel frame on concrete piers. See Figure 6.10 on the preceding page.

6.14 VESSEL MOUNTING/NUMBER OF SUPPORTS

This aspect of vessel design is fairly straightforward, as indicated by the following guidelines:

1. UPRIGHT CYLINDRICAL VESSELS - Should have three supports. Load Cell installation is simplified since load distribution among the supports is automatic. Gapping between the load cell and vessel support due to local support structure deflection caused by traffic or vessel interaction, is impossible for the same reason; three points determine a plane.

2. EXCEPTIONS - Exceptions arise when stability and cost effectiveness are major factors.

   a. Vessels requiring greater stability should have at least four supports; a round vessel with four supports is 22% more stable against tipping than the same vessel with three supports. Vessels in this category are those exposed to high wind or seismic loads, violent internal chemical reactions, or massive fluid sloshing as a result of agitation.

   b. Larger capacity vessels, such as coal silos in excess of 1, 000, 000 lbs., cannot be supported economically on just a few supports. The vessel wall thickness and reinforcement increases as the number of supports decreases. These vessels are usually designed with eight supports, the maximum recommended (load distribution among the load cells becomes problematical with larger number of supports).

   c. Small vessels weighing up to 3, 000 pounds may be suspended from a single cell in tension.

3. RECTANGULAR VESSELS (HOPPERS, BINS) - Generally have four supports; an accommodation to the vessel geometry, symmetry, and steel structural framework.

4. HORIZONTAL CYLINDRICAL VESSELS

Usually have two saddles positioned symmetrically a short distance in from the ends. Three or four supports are placed under the saddles, depending upon the stability and accuracy required. See Figure 6.11.

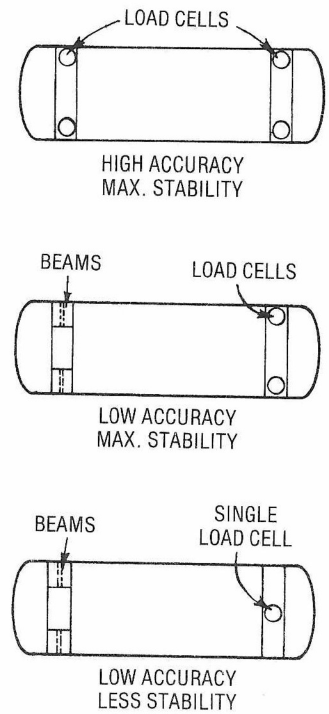

Figure 6.11. Horizontal Cylindrical Vessels

6.15 LOAD CELL SELECTION

Load Cell Capacity is determined in the following manner:

1. Estimate vessel "tare" weight, the weight of the empty vessel plus attached piping, agitators, vibrators, insulation, and vessel heating fluids, as appropriate.

2. Determine the maximum weight of the vessel contents, or "live load".

3. Add the tare weight and live load to obtain the "gross vessel weight".

4. Divide the gross weight by the number of vessel supports and multiply by 1.25 to yield the minimum recommended load cell capacity:

$$\text{Cell Capacity} \quad 1.25K \frac{\text{Gross Vessel Weight}}{\text{Number of Supports}}$$

where K = Dynamic Load Factor = 1

5. The 1.25 factor is an allowance for low tare estimates and unequal load distribution on the load cells.

6. In installations where dynamic loads are anticipated, such as vessels loaded with crane buckets, vessels with horizontal agitators, or dynamometer applications, "derate" the load cell capacity by letting K = 1.25. This will provide greater assurance that the load cell will endure repeated impact loads or high cycle fatigue.

7. A general rule for high accuracy weigh systems with K = 1 is that the load cell(s) should provide a minimum output signal of about 1.0 mv/v over the range of live load.

6.16 LOAD CELL TYPE

Many types of load cells are manufactured to suit a variety of applications; general purpose, precision, high temperature, and rugged environment. General purpose cells are suitable for low accuracy systems; precision cells with tighter accuracy specifications are intended for high accuracy installation. High temperature cells are for use at ambient temperature above 130° and incorporate materials that function under continuously elevated temperatures. Ruggedized cells are designed for mechanical abuse.

6.17 ENVIRONMENTAL PROTECTION

Load cells may be ordered with optional protective coatings to improve the life of the units under adverse environmental conditions. This includes such items as sea water immersion and the presence of harsh chemicals.

6.18 LOAD CELL TERMINATION

Typically, load cells are supplied with 10 feet of integral cable. Other lengths or types of cables for special environments are available.

6.19 LATERAL RESTRAINTS/STAY RODS, SAFETY CHECK RODS

Lateral restraints are mechanical devices designed to secure a weigh vessel to the structure, to maintain initial alignment throughout service life. Unlike unweighed vessels with support brackets that may be bolted or welded directly to the structure, weigh vessels mount on load cells that provide only vertical reactions at one point under the support bracket. While there is some restraint available through friction, relying on this would be detrimental to weigh system accuracy. With few exceptions, it is advisable to apply some form of restraint to all weigh vessels for reasons of:

1. SAFETY - Attached piping can be fatigued or ruptured, or vessels can be upset by unrestrained vessel motion in response to a number of forces prevalent at industrial sites. Systems containing hazardous materials are of particular concern.

2. WEIGH SYSTEM ACCURACY AND STABILITY - Vessel translation, vibration, or oscillation must be properly controlled, or the system calibration accuracy and stability cannot be maintained. For example, vessel translation can apply sideloads on the transducers causing readout errors; vessel vibration and oscillation generates variable signals which may impair the system response or control functions.

6.20 PARTIAL LISTINGS OF OPERATIONAL AND ENVIRONMENTAL ELEMENTS ACTING TO DISTURB A VESSEL

1. Internal to Vessel:

   a. Fluid sloshing.

   b. Violent chemical reactions.

   c. Material entry and exit (thrust and impact forces due to mass flow).

2. External to Vessel:

   a. Vibrators or live bottoms.

   b. Agitators.

   c. Thermal expansion of attached piping.

   d. Structural support vibration from rotating equipment or traffic.

e. Structural support deflection from adjacent vessels, equipment or traffic.

f. Potential impact from traffic or overhead crane.

g. Seismic events.

6.21 STAY RODS/SAFETY CHECK RODS

Experience has shown the use of tension straps to be a simple and effective means to vessel restraint. In the usual configuration, straps are arranged in pairs; one pair for each load cell on the vessel, positioned symmetrically about, and tangentially to the vessel. There are two major categories of tension straps:

1. STAY RODS constitute the primary lateral restraint system on most vessels and are intended to rigidly constrain or "stay" the vessel. These rods are installed snugtight between a gusset on the vessel support bracket and a rigid floor bracket a few feet away. Vessel translation or rotation is thus restricted, while radial thermal expansion is relatively unimpeded. Because stayrods are snug to the vessel, they are an active part of the weigh system and must be installed level to insure a linear response with deflection.

2. SAFETY CHECK RODS are backup members whose sole function is to hold the vessel in "check", preventing gross tipping or wobbling. These tension straps are installed with a loose fit so that they do not interact with the weigh vessel even after thermal

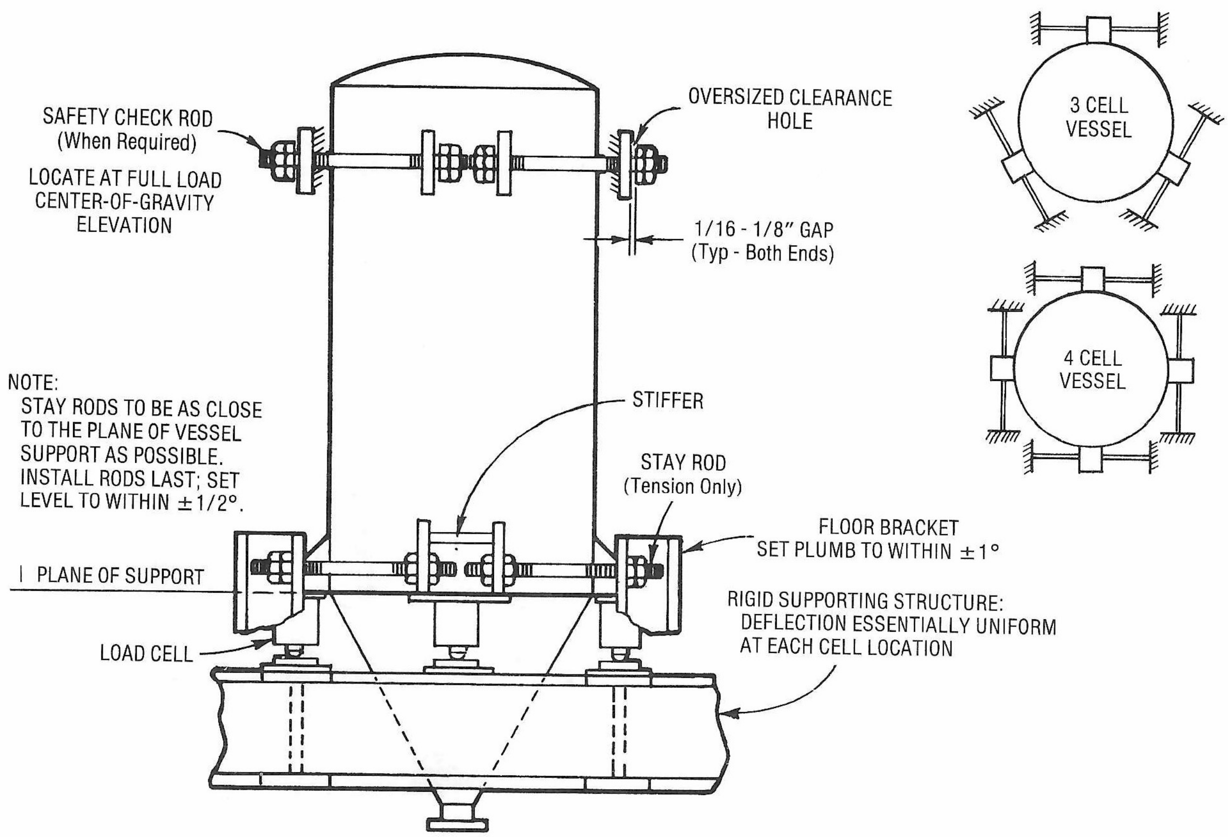

Figure 6.12. Typical Rod Arrangement

growth. They simply contribute to the vessel tare weight. Safety check rods are positioned at vessel elevations other than the plane of support to guarantee stability for those vessels with large height-to-width ratios, such as tall storage silos. See Figure 6.12 on preceding page for Typical Rod Arrangement.

The stay rod has the following advantages:

By terminating the rods at floor brackets adjacent to the vessels instead of available structure, the rod end deflection is efficiently limited to the load cell compression (0.010") or tension linkage elongation (0.030"). This is much less than the overall floor deflection between the vessel and structure. Therefore, the likelihood of significant mechanical restriction arising from stay rods is greatly reduced.

The majority of vessels have support brackets located near the maximum center-of-gravity elevation. Many other forces (e.g., seismic or wind) act at or near this location. Installation of the rods at the brackets removes these forces at the point of application, leaving the vessel relatively unloaded.

By terminating the rods at a gusset plate on the vessel support bracket, a separate reinforced attachment area on the vessel wall and a separate stay rod fitting are avoided.

Thermal expansion between the plane of support and rod attachment point becomes trivial, and the restraint may be located outside the vessel insulation, simplifying installation.

The use of floor brackets provides more open space around the vessel, improving access to the vessel.

Lateral restraints are not necessary for vessels that meet all requirements listed:

1. Essentially static contents; no significant agitation or vibration.

2. Essentially static environment, no possiblilty of large external forces such as wind, excessive support structure vibration, wayward forklift, or seismic event (seismic zones 0 to 1 only).

3. Three or more supports.

4. Plane of support is near maximum center-of-gravity (CG) elevation.

5. Either no direct piping contact (vented systems) or only very flexible nonmetallic connections (sealed systems).

6. Slow material flow rates (sealed systems).

7. Mounted in tension or rest on fixed

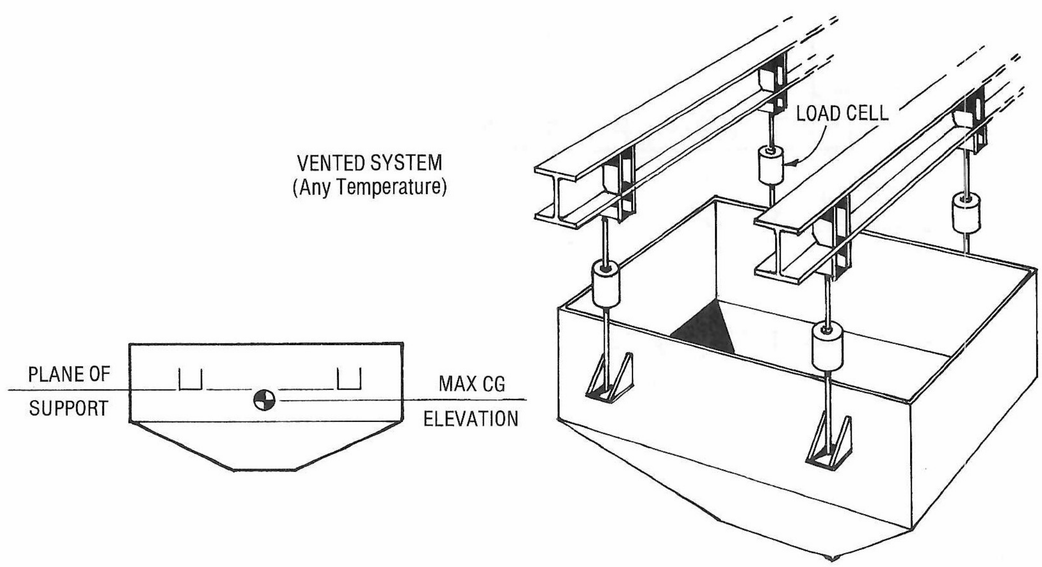

Figure 6.13. Vented Systems (Any Temperature)

mounting plates. See Figure 6.13, Vented System (any temperature) on preceding page.

NOTE

Should minor disturbances be present or expected, safety check rods or some form of bumper may be added to preclude large vessel motion. This is possible only for vessels that will return to their original position after the disturbance is over; e.g., vessels supported in tension or compression at or above their maximum CG elevation. See Figure 6.15 for Sealed System Ambient Temperature Only.

Lateral Restraints are not necessary for vessels meeting the requirements listed on page 10.

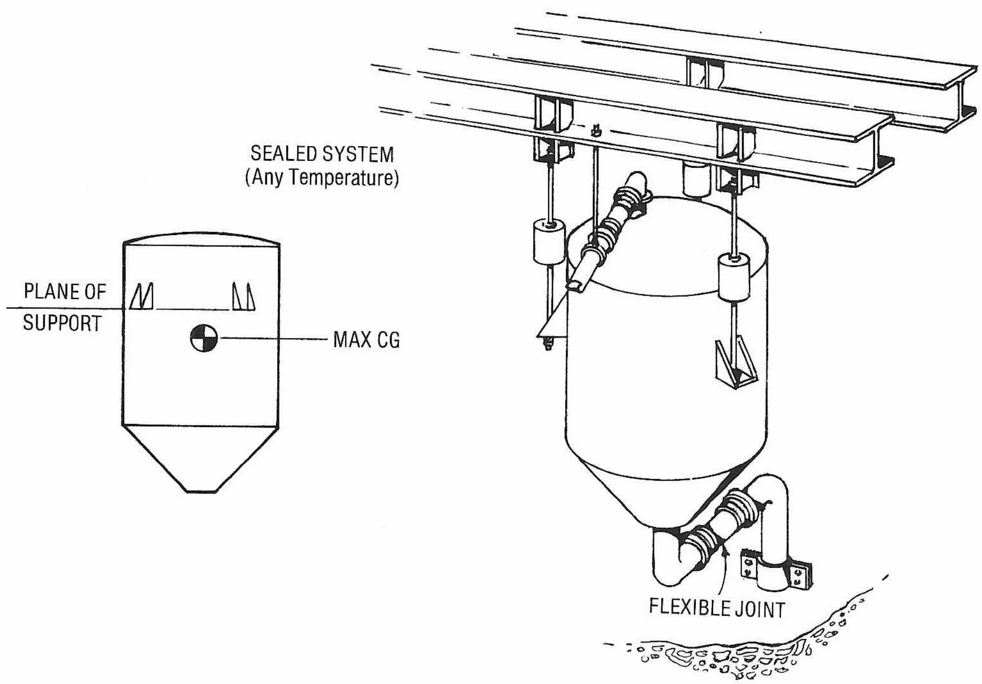

Figure 6.14. Sealed System (Any Temperature)

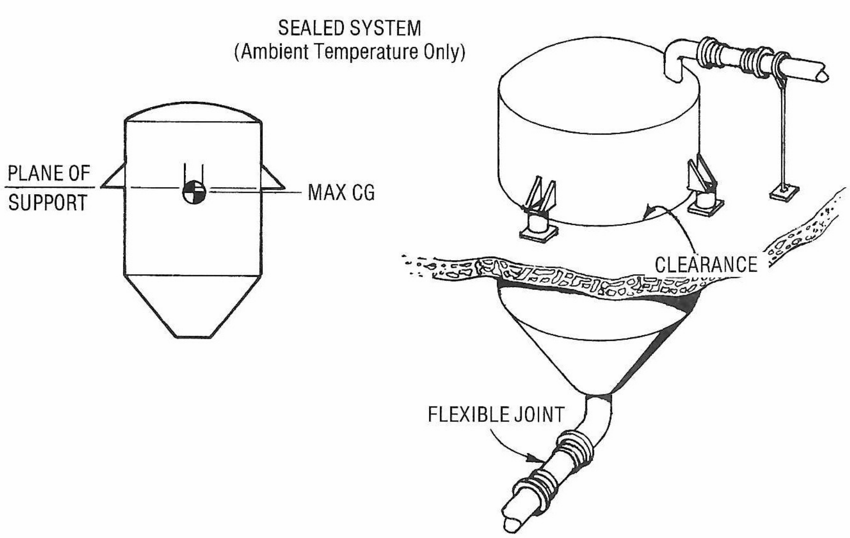

Figure 6.15. Sealed System (Ambient Temperature Only)

Lateral Restraints are essential for vessels subjected to one or more of the following:

1. Low friction expansion assemblies are used; restraints required to maintain intial vessel alignment.

2. Very active contents; sloshing or violent chemical reaction.

3. Active environment; wind, structural vibration, vehicle threat, or high seismic activity zone (Zone 2 or 3).

4. Large agitator or vibrator.

5. Plane of support well away from the maximum center-of-gravity (CG) elevation.

6. Top heavy or heavy off-centered auxiliary equipment.

See Figure 6.16 thru 6.22 for illustrated examples of Lateral Restraints for various assemblies of vessels.

NOTE

When the significance of disturbing forces is uncertain, it is good practice to design the restraint system, provide attachment points on the vessel, and then see how the vessel functions in operation. If restraints are required, the space should be available and the restraints can be added.

Lateral Restraints are essential for vessels subjected to one or more of the factors listed above.

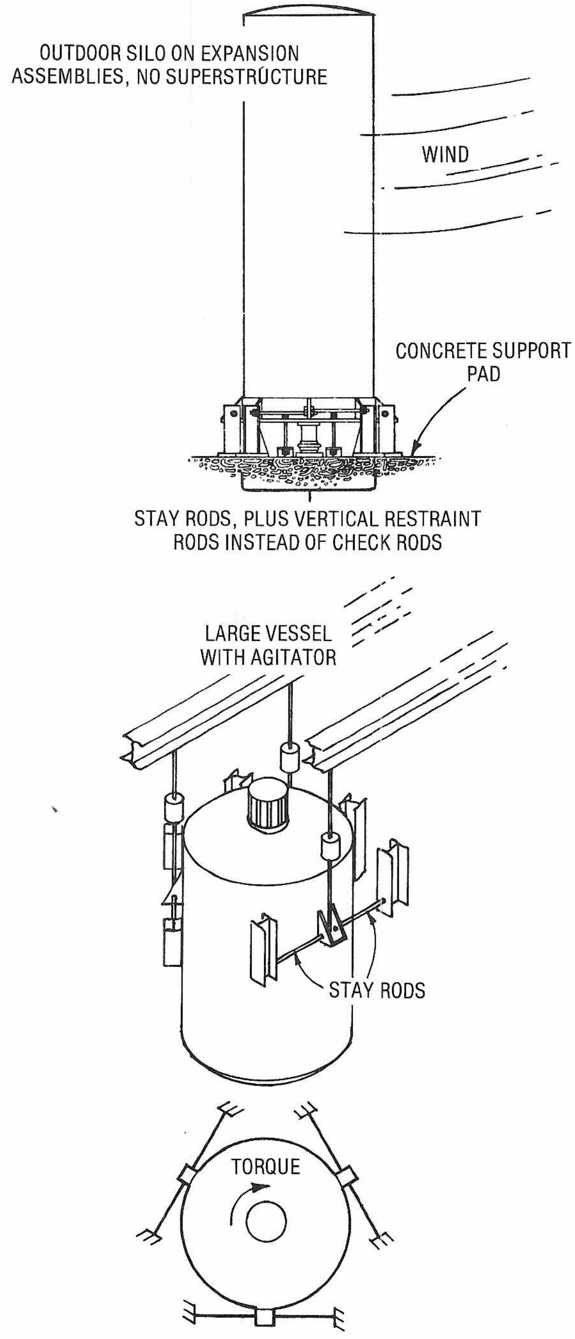

Figure 6.16. Lateral Restraints

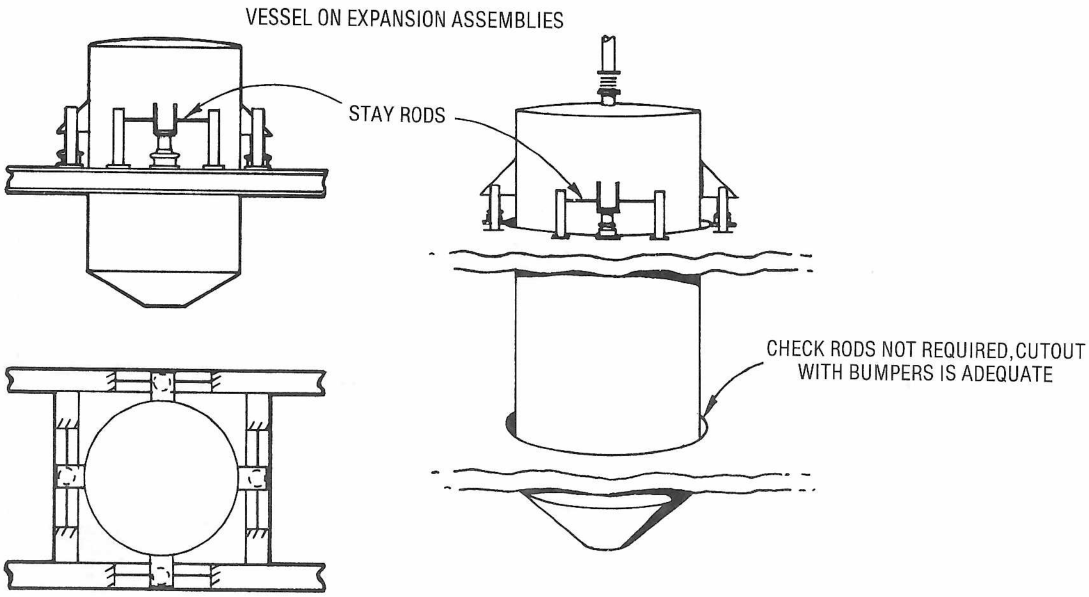

Figure 6.17. Vessels on Expansion Assemblies

Lateral restraints are essential for vessels subjected to one or more of the factors listed on page 6-12.

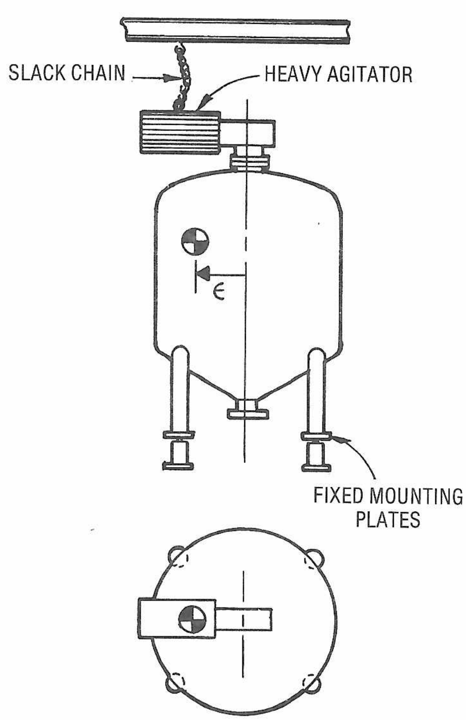

Figure 6.18. Vessels with Offset CG

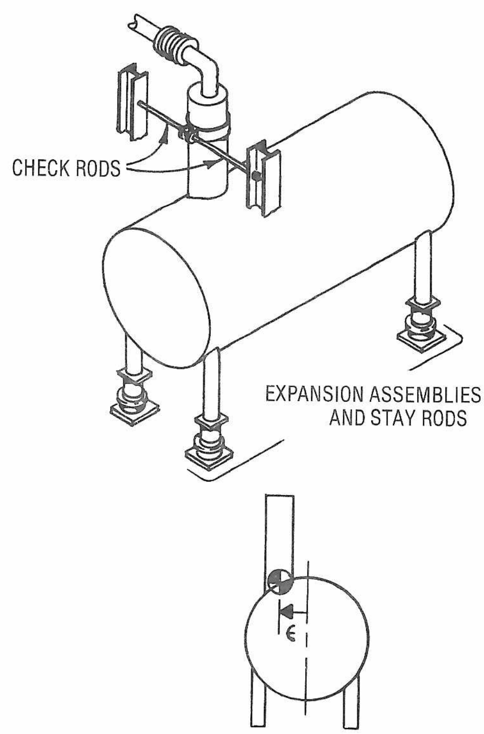

Figure 6.19. Vessels with Offset CG; Expansion Assemblies

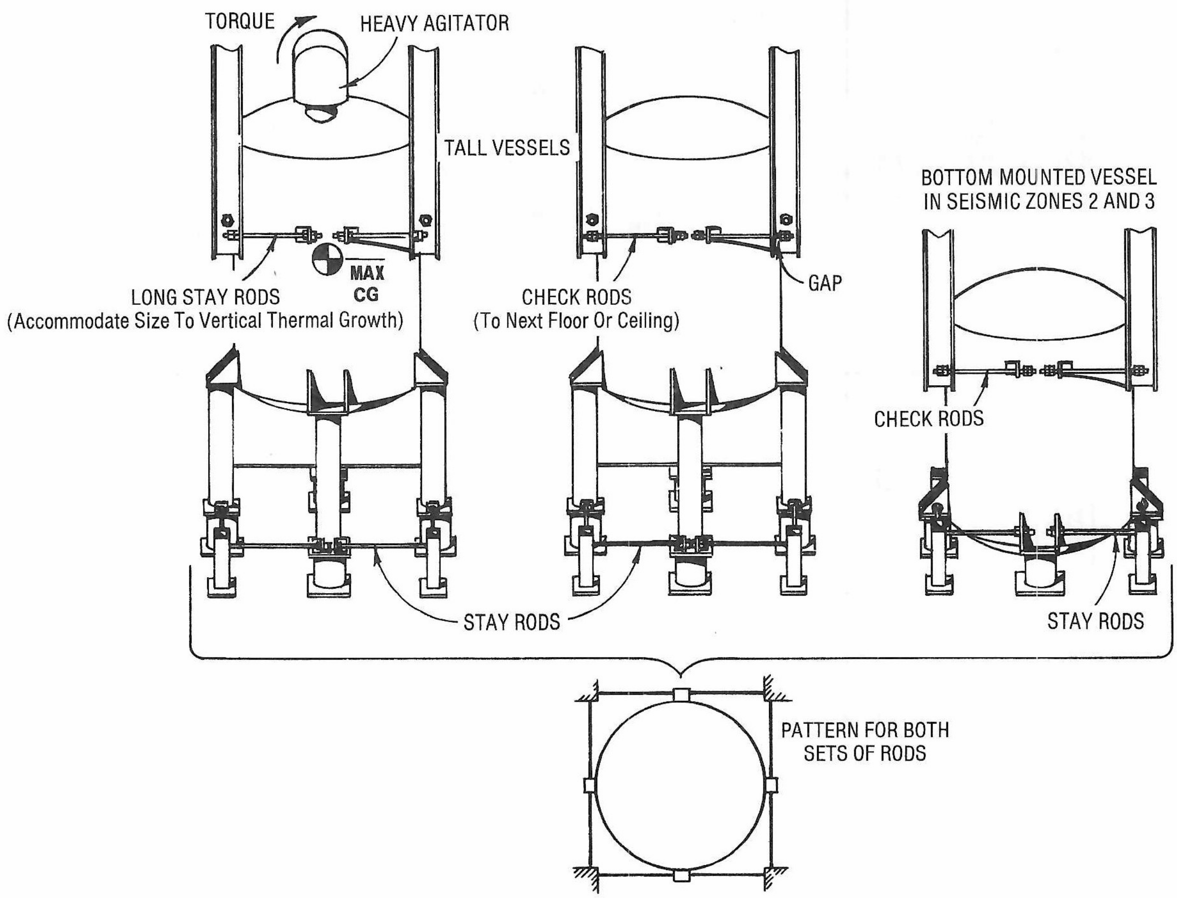

Figure 6.20. Lateral Restraints; Four Cell Mounting

See Figures 6.21 and 6.22 on
the following page.

Lateral Restraints are essential for vessels subjected to one or more of the factors listed on page 6-12.

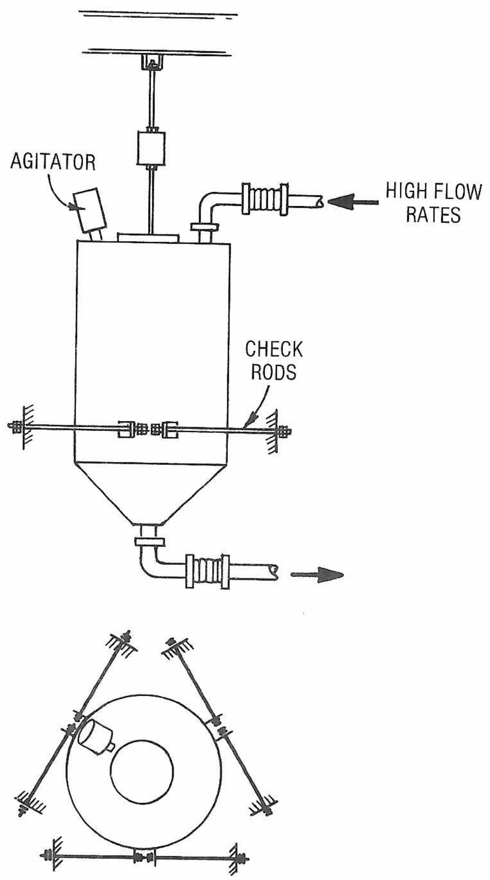

Figure 6.21. Lateral Restraints, Tension Mounting

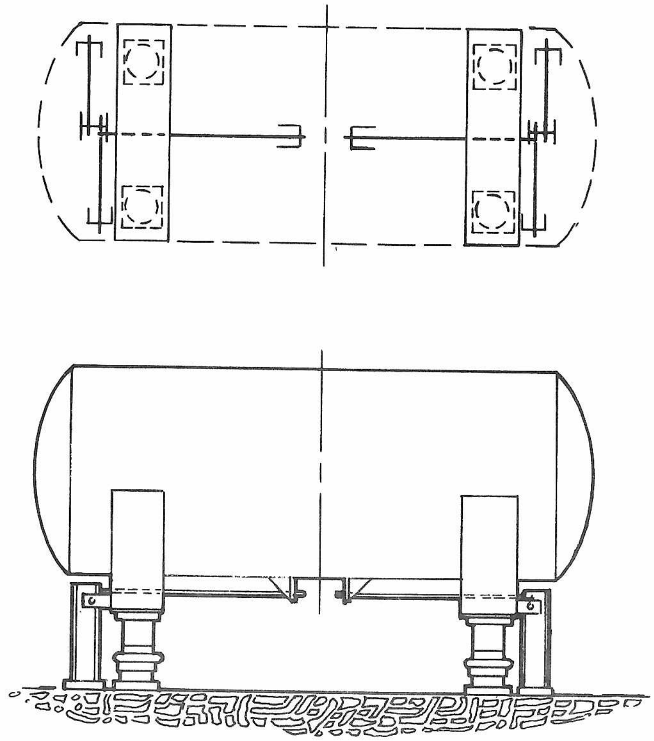

Figure 6.22. Lateral Restraints; Horizontal Tank Mounting