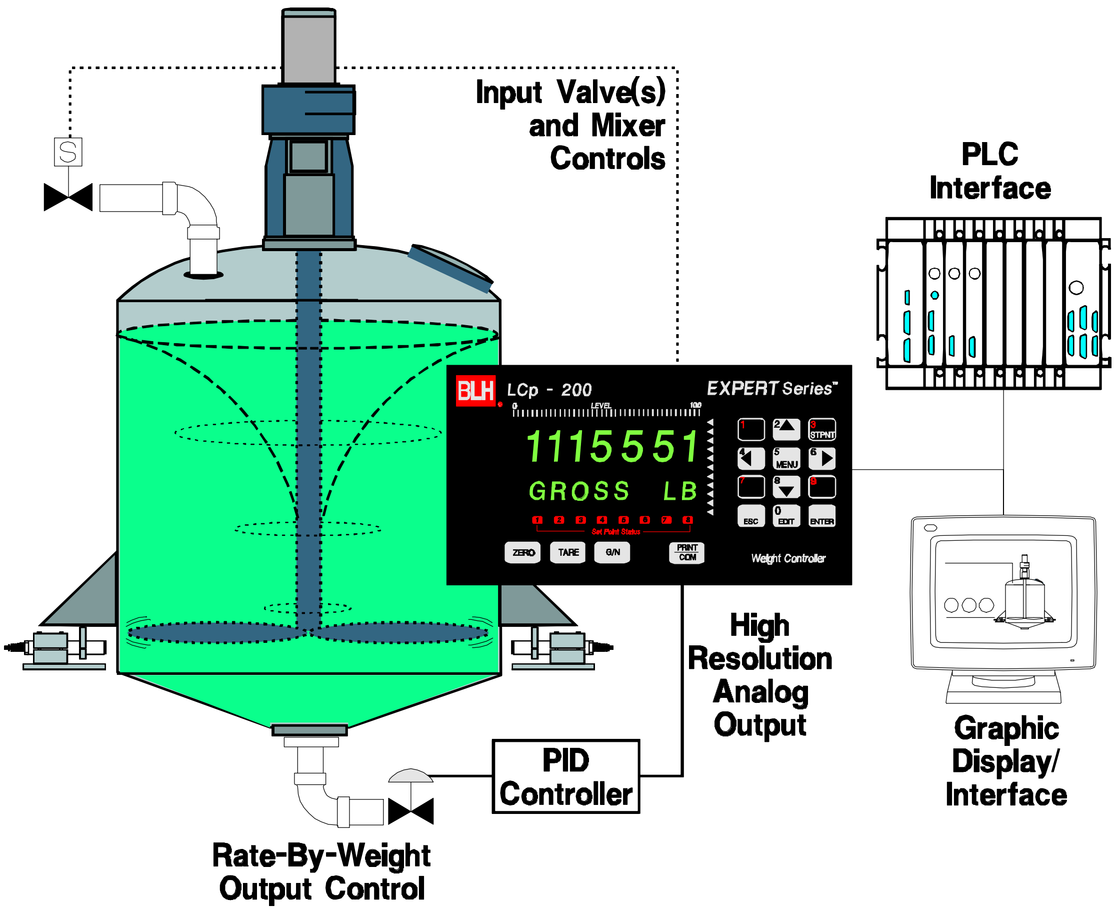
BLH®

BLH Electronics, Inc.
ISO 9001 Registered

Electronic Weigh Systems Handbook



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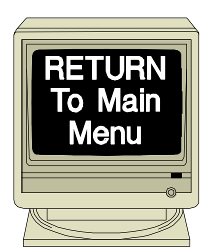

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introduction

Since the beginning of trade, some kind of measure of weight had to be established. Not only did this measure have to be uniform, it also had to be honest. In order to weigh or measure anything, there has to be a standard for comparison. The equal arm balance scale or the unequal arm beam scale has been used for thousands of years as the standard for comparison. It is still, by far, the most commonly used technique in the world for determination of weight. However, approximately forty years ago a novel technique was invented to make electronic weight measurements reliable and economically practical. This invention was the resistance wire strain gage. The strain gage consists of a filament of thin foil or wire which will change resistance when stressed.

Dr. Arthur C. Ruge of M.I.T. and E. E. Simmons of CalTech are credited with the simultaneous, but independent invention of the strain gage in 1937/38. Since each inventor had an assistant working on their project, and, since a total of four people worked on the invention, the trade name for this strain gage became SR-4® (**S**immons **R**uge - **4** people).

Professor DeForest, an inventor in his own right who produced a mechanical strain gage, encouraged Dr. Ruge in his work. From this relationship between two educators/scientists grew the Ruge-DeForest partnership which manufactured strain gages sold by Baldwin in the 1940's. In 1939, Ruge had signed an agreement with Baldwin Locomotive Works whereby he would design and manufacture SR-4® strain gages to be marketed by Baldwin. This arrangement continued until 1955 when Baldwin-Lima-Hamilton (BLH), which had acquired Baldwin Locomotive Works, bought Ruge-DeForest, Inc.

BLH Electronics, with a history that spans more than forty years, offers a product line that extends from basic sensors and signal conditioners to highly sophisticated, computer-based process control systems....plus all the related services from concept to start-up.

Strain gages, as invented by Dr. A.C. Ruge, are now commonly used to determine stresses in a myriad of applications. The first electronic signals transmitted from the moon came from SR-4® strain gages attached to the three legs of the Lunar Surveyor. These strain gages measured the deflection of the legs upon impact with the moon. Scientists analyzed these signals and determined the consistency of the lunar surface.

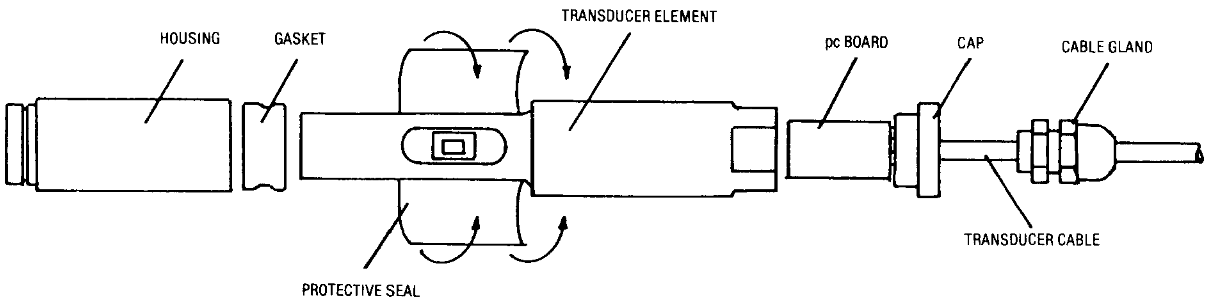
When a strain gage is bonded to a piece of metal and the metal is loaded with a weight or force, the resistance change of the strain gage can be related directly to the weight or force placed on this piece of metal. The first industrial load, pressure and torque transducers using the strain gage technique were developed by Ruge in 1942 and 1943. These were rugged units with large overload capacities because the cells often were subjected to excessive abuse by workers who were unfamiliar with the devices. Unlike today's BLH high precision load transducers, the early transducers were accurate only to 0.25% of full scale and available in limited weight capacities. Since then, BLH Electronics has made load transducers with the capacity of 4 million lbs, to determine the weight distribution of the Saturn rockets when moved from the assembly area to the launching pad on monstrous crawlers, to capacities of a few ounces in order to determine the number of food stamps in a given stack.

The load transducer for electronic weighing has now been universally accepted. BLH Electronics has thousands of strain gage-based weighing system installations all over the world. It is the intent of this weigh systems handbook to help the user in avoiding some of the problems which may occur to degrade the accuracy of a weigh system. Many of the suggestions for this book came from the BLH Field Service Group. The book, therefore, is mostly practical with, here and there, a sprinkling of theory.

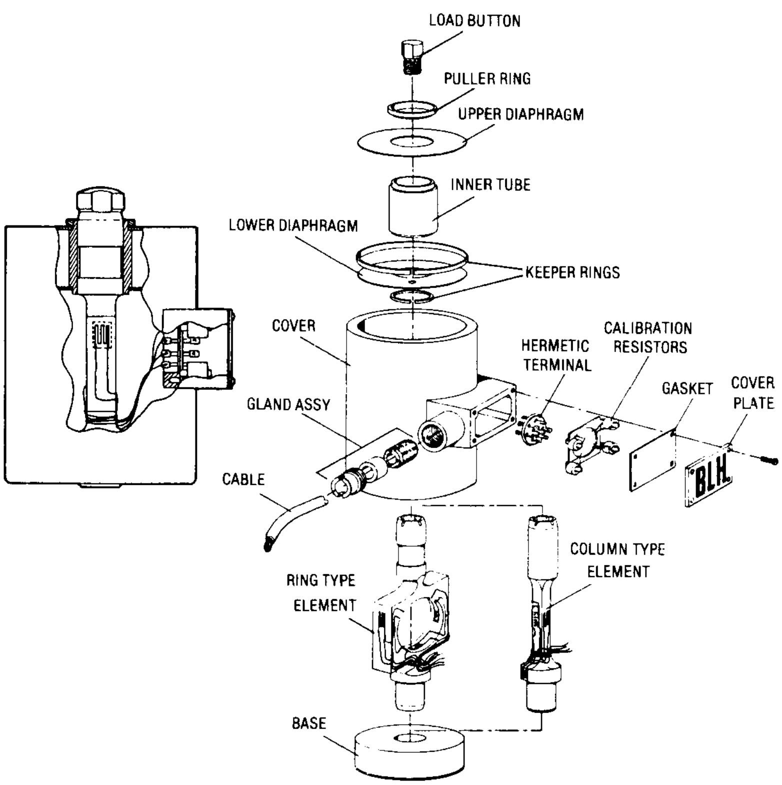
introduction

The load transducer

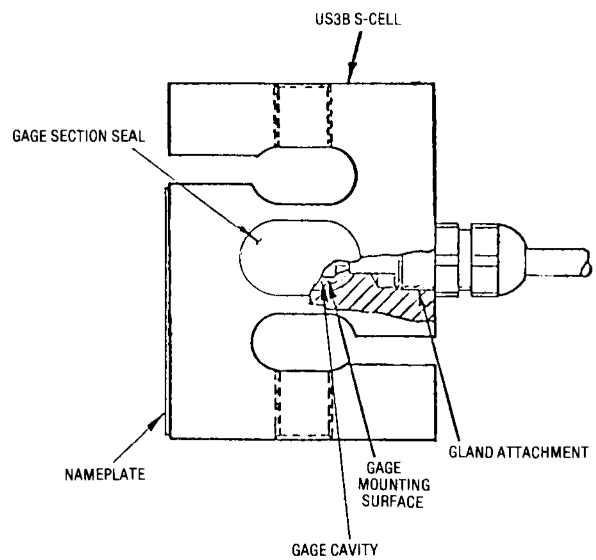
The term 'electronic weighing' as used in this book is based upon the load transducer which derives its principals from the strain gage. The load transducer consists of an elastic element to which strain gages are bonded. Upon applying the mass to be measured to the elastic member, the strain gage will change its resistance in direct proportion to the mass applied. Load transducers, therefore, are electronic devices that translate changes in force into changes in resistance. Typical load cell, KIS beam, and S-cell construction is shown in the following illustrations.



KIS BEAM CONSTRUCTION



CANISTER TYPE LOAD CELL CONSTRUCTION



S - CELL CONSTRUCTION

introduction

Four SR-4® strain gages are used in each load transducer and connected in a fully active, four-arm Wheatstone bridge. Precision resistors are added at different locations in the circuitry to compensate for temperature effects. Typical standard compensated values for load transducers are eight parts per million (ppm) per degree Fahrenheit for the output change with temperature and fifteen ppm/°F for the zero change with temperature.

In order to protect the element from the outside environment, the sensing portion of the load transducer is enclosed in a sealed cover. Each load transducer sold by BLH has special inherent features to protect the sensing element from the effects of side loading.

Why electronic weighing

The majority of electronic weighing systems are used for one of the following purposes:

REDUCE INVENTORY COSTS - Efficient and accurate control of inventory by weight allows the user to maintain the optimum amount of material on hand for efficient production without costly excesses. Accurate inventory can also result in a reduced number of storage vessels and area, contributing to further cost savings.

REDUCE LABOR COSTS - Process automation through installation of automatic batching systems can eliminate a substantial amount of manual input. Centralized inventory control readouts obviate the need for visual inspection of storage areas.

IMPROVE PRODUCT QUALITY - Accurate batch control improves the consistency of end product quality resulting in improved product acceptance and reduces costly product rejects and rework.

It is easily understood why an electronic weigh system has advantages over a mechanical beam type system. Some of the advantages are:

1. Due to the low deflection of the load transducer, a load transducer based weighing system has a fast response or settling time.
2. The higher the capacity of the weighing system, the lower the cost will be of the weighing structure.
3. Remote measurements can be made.
4. The weight information can be processed directly to eliminate human error.
5. Microprocessor based instrumentation can communicate directly with programmable controllers or process computers.
6. Electronic weighing systems often can be adapted to existing installations.
7. Load transducers and associated electronics are solid state devices and, therefore, are not subjected to wear such as found in the knife edges and supports in mechanical systems.

Overview of electronic weigh systems

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 obviously a function of the instrumentation, is also 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 inexorably tied to the degree of attention given to the mechanical details.

HIGH ACCURACY WEIGH SYSTEMS exhibit system errors under 0.05% for Buy-and-Sell to 0.25%. To achieve this, the following mechanical requirements are imposed:

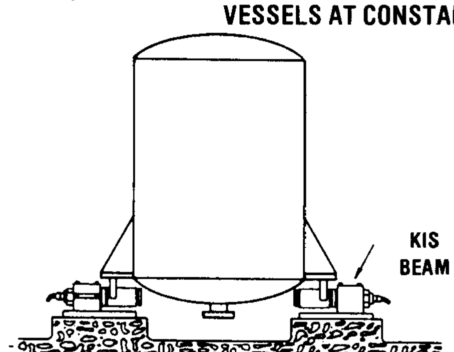
- The weigh vessel must be fully supported by transducers. The number of load transducers may vary from one (in tension) to eight (in compression). Generally, as the number of load transducers decreases, the vessel wall thickness and support structure stiffness must increase to carry the higher vessel support reactions.
- Precision load transducers with full temperature compensation must be used.
- Mechanical restrictions from attached piping and lateral restraints should be avoided. Highly flexible piping attachments are recommended.
- Hot gas or steam-heating schemes which produce variable buoyancy should be avoided. Consult factory for alternate solutions.
- Pressurized or vacuum vessels also produce variable buoyancy, an effect which can be electrically compensated by means of a pressure transducer wired into the load cell circuit.

LOW ACCURACY WEIGH SYSTEMS are those with a system error greater than 0.5%. Mechanical considerations are relaxed considerably:

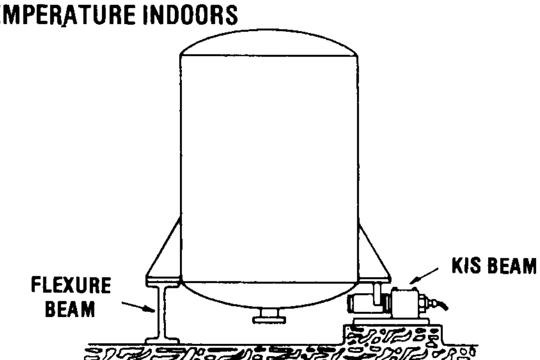
- The weigh vessel need only be partially supported by load transducers, usually one or two on any side or end of the vessel. This, however, requires the contents to be self-levelling and the vessel itself to be without partitions, so that the load fraction carried by the load transducers is unchanging. (Vessels falling into these two categories must be fully supported, independent of the accuracy required.)
- Modest mechanical restrictions may be tolerated, but nonlinear mechanical hangups or frictional interfaces must still be avoided.
- General purpose transducers are satisfactory for these systems.

Systems in compression

VESSELS AT CONSTANT AMBIENT TEMPERATURE INDOORS

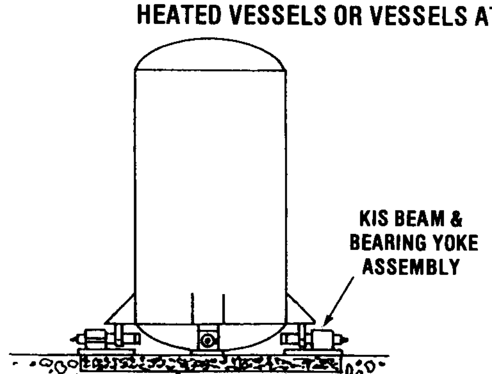


HIGH ACCURACY
FULLY SUPPORTED

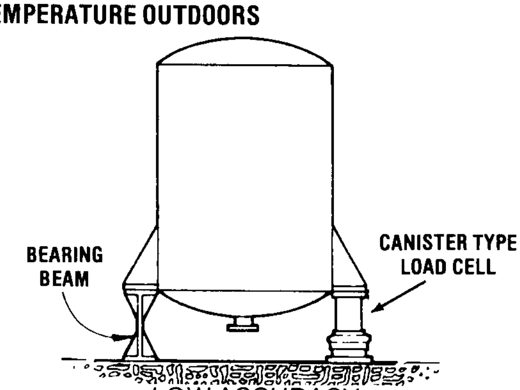


LOW ACCURACY
PARTIALLY SUPPORTED

HEATED VESSELS OR VESSELS AT AMBIENT TEMPERATURE OUTDOORS



HIGH ACCURACY
FULLY SUPPORTED

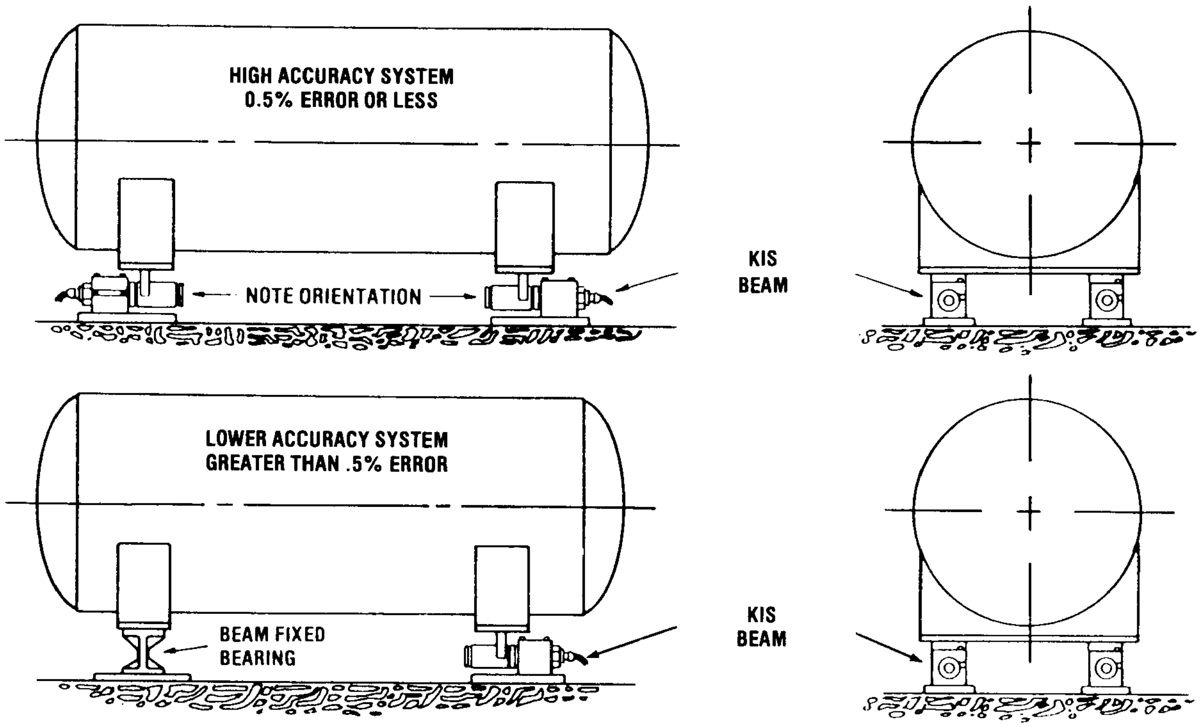


LOW ACCURACY
PARTIALLY SUPPORTED

general considerations

Systems in compression

HORIZONTAL TANKS

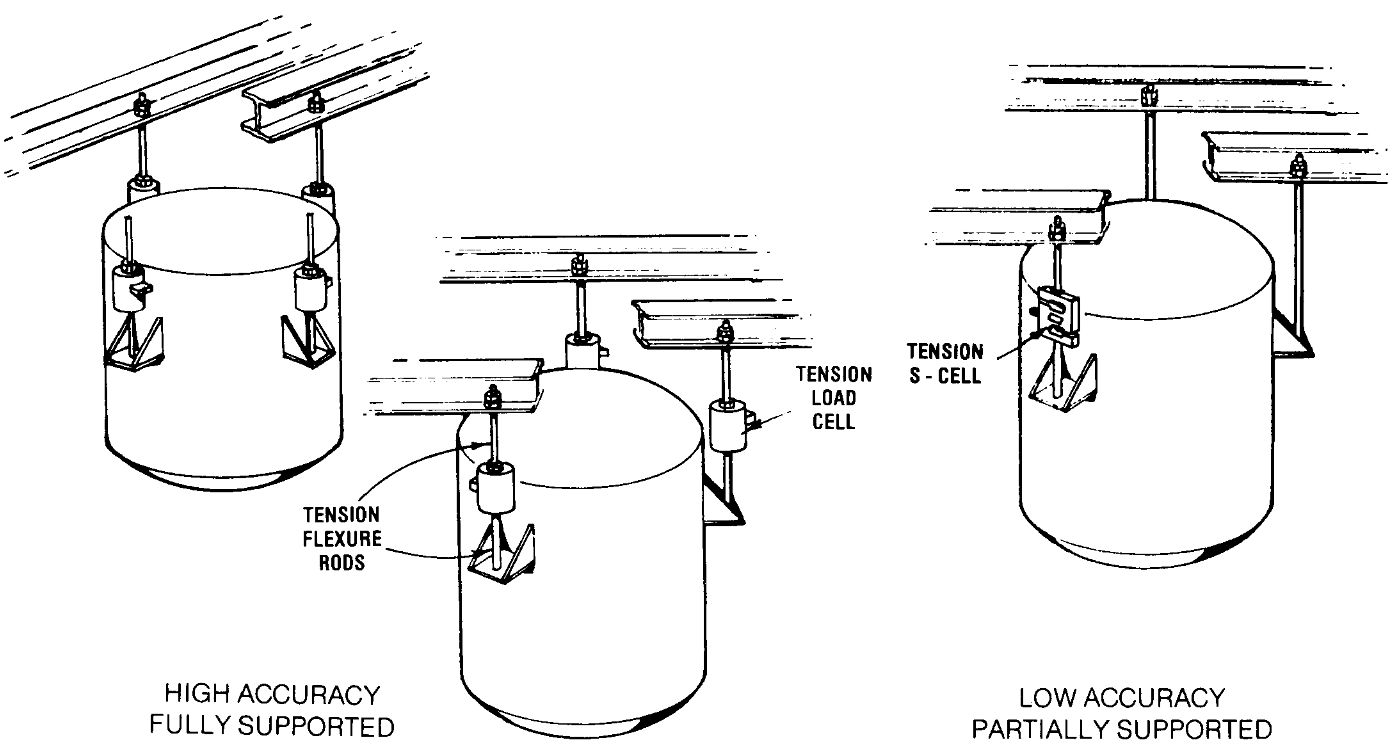


A horizontal tank supported by four KIS Beams yields a high accuracy weigh system independent of material location. A lower accuracy system suitable for unpartitioned vessels with self-leveling materials requires only two KIS Beams.

Systems in tension

VESSELS AT ANY TEMPERATURE

(Lengths of Tension Flexure Rods are sized to accommodate radial thermal expansion)

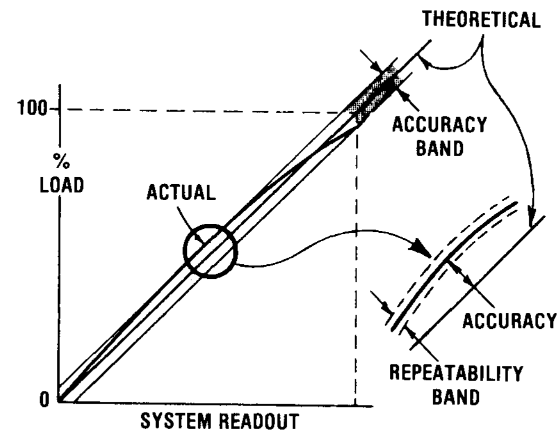


HIGH ACCURACY
FULLY SUPPORTED

LOW ACCURACY
PARTIALLY SUPPORTED

Accuracy vs. repeatability

- DO NOT CONFUSE SYSTEM ACCURACY WITH REPEATABILITY! As long as the mechanical error in a given system is linear with deflection and independent of the environment (temperature, traffic, surrounding vessels, etc), the inherent system repeatability will be greater than its accuracy. For example, a BLH Model 4315A Transducer Indicator has an overall accuracy specification of 0.01% of reading, ±1 count, of which repeatability is but a small fraction. BLH load transducers, meanwhile, typically display a repeatability of 0.01 to 0.02%. Thus, most BLH 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 always performed employing a dead weight method.



- DEFINITIONS:

  ACCURACY — Ability of the system to perform weighing functions within an acceptable or desirable tolerance; usually stated as a percentage of either full scale reading, or ±n count(s) referred 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.

Vessel mounting — tension or compression

Either method routinely yields high accuracy weigh systems and, except for the few observations presented below, there is little to recommend one over the other. In most cases, plant layout is the determining factor.

MAXIMUM WEIGH SYSTEM ACCURACY AND STABILITY will be obtained when the vessel is mounted in compression on a rigid concrete foundation. This arrangement avoids all the usual sources of deflection,variations in load transducer alignment, and vibration that act to compromise calibration accuracy and operational stability. Therefore, when extreme accuracy is required (<0.05%), this approach should be considered first.

VESSELS WEIGHING UP TO 3,000 pounds are candidates for the simplest system, a single canister type load or S-Cell (BLH Model U3SB) in tension - providing that lateral restraints may be added if required to keep the vessel from tilting, swaying, and rotating.

general considerations

Vessel mounting — tension or compression (continued)

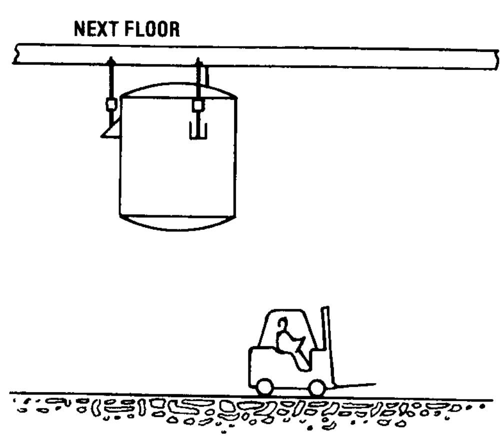
Other considerations

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 very 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 Transducer Alignment	Canister type load cell alignment may vary during service due to overall floor deflection, local support beam twist, or vessel deformation causing 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 or bearing yokes (KIS Beams) are required to accommodate differential thermal expansion or contraction between the vessel and support structure. Thermal insulation pads minimize heat conduction to load transducers.	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	Lateral restraints are usually unnecessary in KIS beam applications. However, lateral restraints are almost always necessary for canister type load cells, except when the vessel is at ambient temperature, off in a corner, 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 because of the reduced structural stiffness and damping capability caused by the tension linkage and the likelihood of the vessel's having a small mass more readily set in motion.

Some plant layout factors

OPEN SPACE REQUIREMENT

If the area beneath the vessel must be uncluttered, tension mounting is an option to be considered.

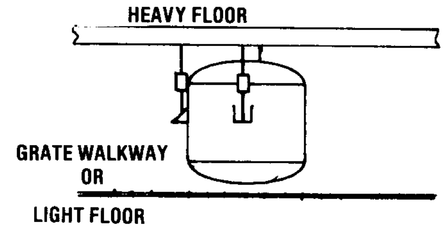


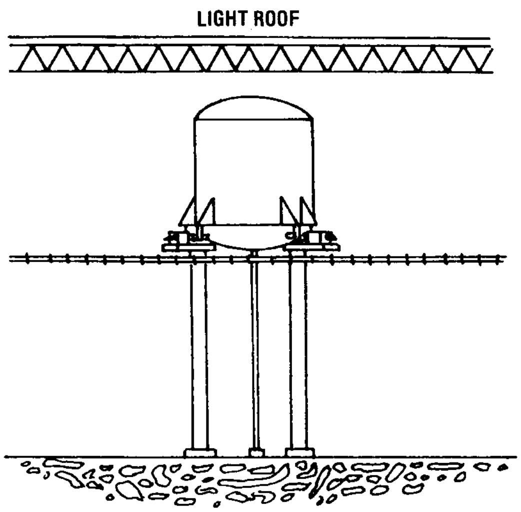
Vessel mounting — tension or compression (continued)

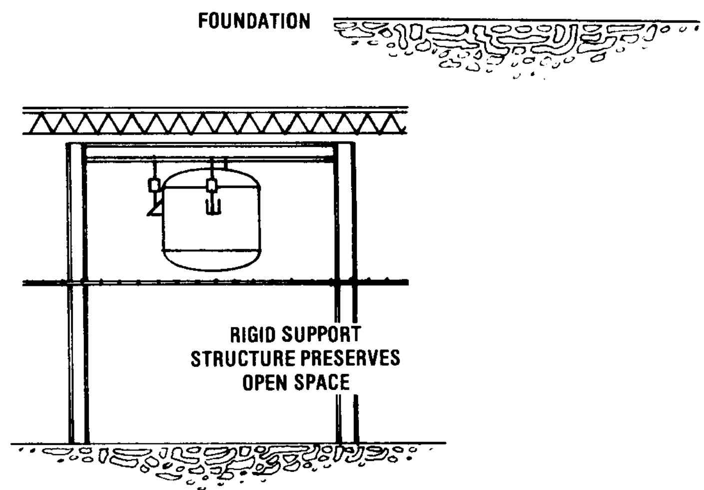
Some plant layout factors (continued)

WEAK FLOOR OR NO FLOOR

When upgrading an older plant, where a convenient floor exists but is too weak to carry a new weigh vessel, or where there is no convenient structure, the weigh vessel may require a special installation as shown here.

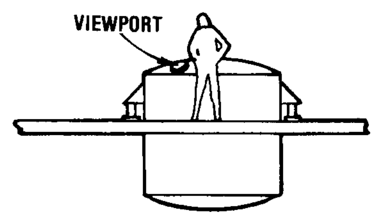


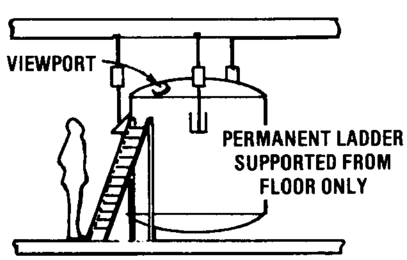




ACCESS FOR INSPECTION

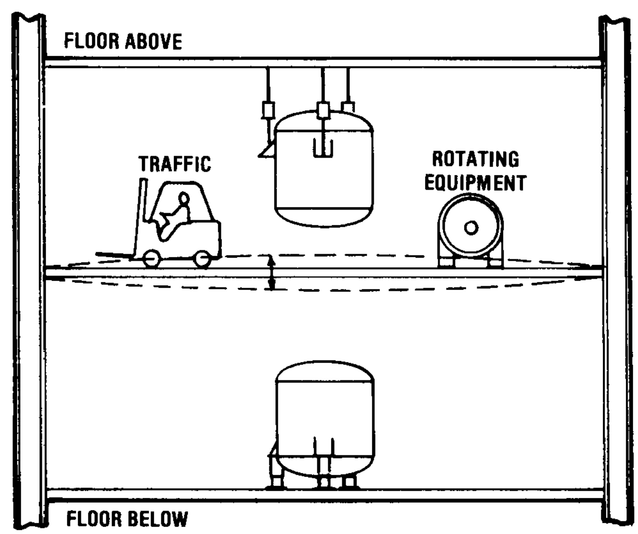
When processes must be monitored via vessel viewports, arrangements must be made such that the observer does not load the vessel.





FLOOR VIBRATION OR DEFLECTION

Avoid mounting a vessel to a support structure subject to deflection or vibration from traffic or rotating equipment.



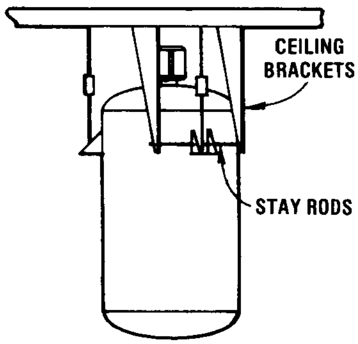
general considerations

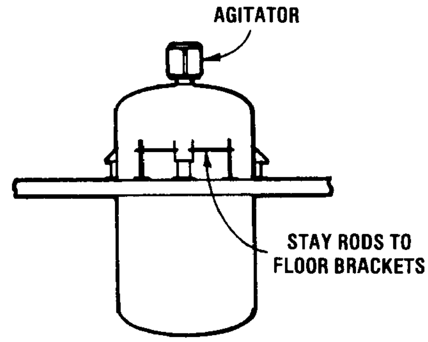
Vessel mounting — tension or compression (continued)

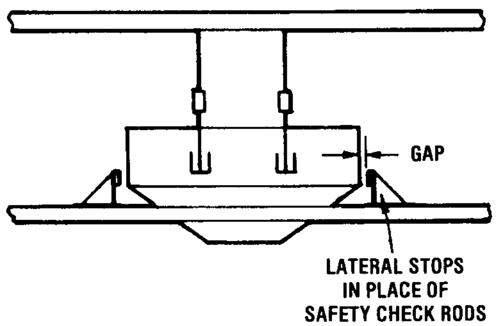
Some plant layout factors (continued)

LATERAL RESTRAINT INSTALLATION (Load and S-Cells)

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

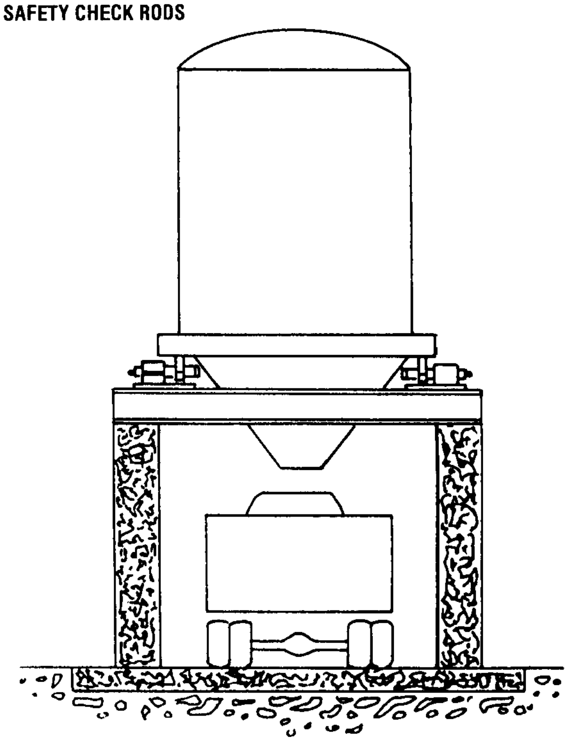


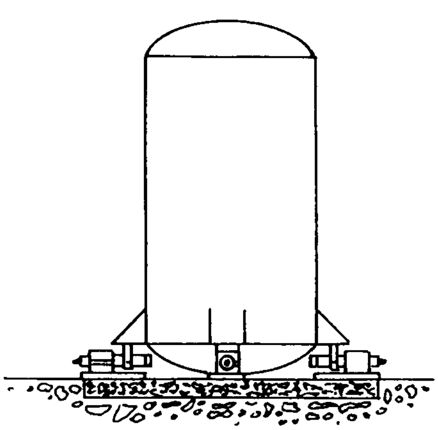


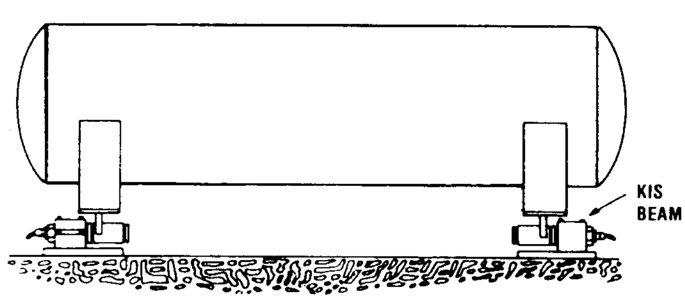


OUTDOOR LOCATION

Vessels situated outdoors are usually mounted 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 elevated by a steel frame on concrete piers.







Vessel mounting — number of supports

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

- UPRIGHT CYLINDRICAL VESSELS should have three supports. Load transducer installation is simplified since load distribution among the supports is automatic; gapping between the load transducer and vessel support due to local support structure deflection in response to traffic or vessel interaction is impossible for the same reason - three points determine a plane.

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

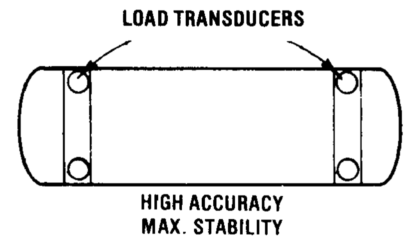
  Vessels requiring greater stability should have at least four supports; a round vessel with four supports is 22% more stable against tipping than the same vessel with three supports. In this category are vessels exposed to high wind or seismic loads, violent internal chemical reactions, or massive fluid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

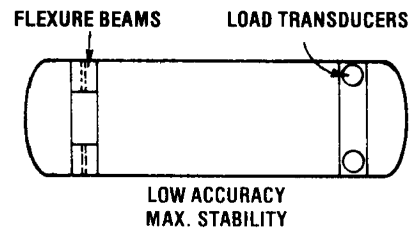
  Vessels of large capacity such as coal silos in excess of 1,000,000 pounds cannot be supported economically on just a few supports since vessel wall thickness and reinforcement increases as the number of supports decreases. These vessels are usually designed with eight supports, the maximum recommended by BLH Electronics. (Load distribution among the load transducers becomes problematical with larger numbers of supports.)

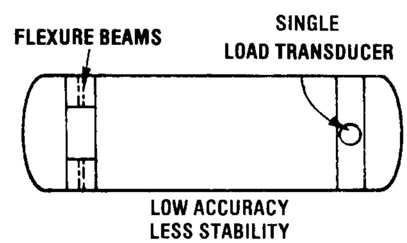
  Small vessels weighing up to 3,000 pounds may be suspended from a single cell in tension.

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

- 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.







Load transducer selection

LOAD TRANSDUCER CAPACITY is determined in the following manner:

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

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

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

- Divide the gross weight by the number of vessel supports and multiply by 1.25 to yield the minimum recommended load transducer capacity;

$$\text{Capacity} = 1.25\,K\,\frac{\text{Gross Vessel Weight}}{\text{Number of Supports}}$$

Where K = Dynamic Load Factor = 1

- The 1.25 factor is an allowance for low tare estimates and unequal load distribution on the load transducers as installed.

Load transducer selection (continued)

- In installations where dynamic loads are anticipated, such as vessels loaded with crane buckets, vessels with horizontal agitators, or dynamometer applications, 'derate' the load transducer capacity by letting K = 1.25. This will provide greater assurance that the load transducer will endure repeated impact loads or high cycle fatigue. Estimate or calculate dynamic forces and consult BLH.
- A general rule of thumb for high accuracy weigh systems with K = 1 is that the load transducer(s) should provide a minimum output signal of about 1.0mV/V over the range of live load. If it does not, consult BLH Electronics for specific recommendations on your weigh system requirements, since electronic techniques can be employed to increase accuracy at lower signal levels.

LOAD TRANSDUCER TYPE

BLH Electronics manufactures many types of load transducers to suit a variety of applications — general purpose, precision, high temperature, and rugged environment. General purpose transducers are suitable for low accuracy systems; KIS Beams, with tighter accuracy specifications, are intended for high accuracy installations; high temperature transducers are for use at ambient temperature above 130°F and incorporate materials that function under continuous elevated temperature operations; ruggedized transducers are specially designed for mechanical abuse. Consult BLH Electronics for specific application recommendations.

ENVIRONMENTAL PROTECTION

Load transducers from BLH Electronics may be ordered with optional protective coatings to improve the life of the units under adverse environmental conditions such as sea water immersion and the presence of harsh chemicals. Consult BLH Electronics for recommended coating systems for your situation.

LOAD TRANSDUCER TERMINATION

BLH Electronics typically supplies load transducers with 10 feet of integral cable. Other lengths or types of cables for special environments are available upon request.

CONVERSION FORMULA

Since some load transducers are specified in terms of 'Newtons', the following formula can be used to convert to pounds or kilograms.

1 Newton = 0.225 lbs = 0.102 kgs
(approximate gravitational equivalent)

Field calibration

VESSELS FULLY SUPPORTED ON LOAD CELLS

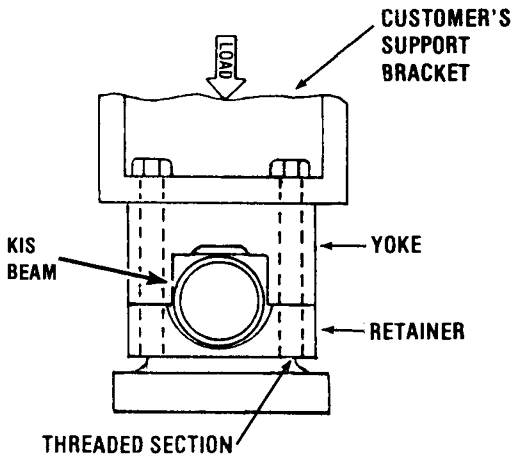
- Calibration to 0.25% of full scale can be performed by electronic substitution using the BLH Model 625 Precision Calibrator or equivalent. This method assumes the vessel to be free of significant mechanical restrictions; i.e., all attached piping can be felt to move under a sharp blow of the fist; no structural hangups will occur when the vessel is fully loaded. Barring any mechanical problems or unusually difficult vessel access, electronic calibration takes just a few hours. Note that load transducer cables should not be shortened substantially when electronic calibration is used.
- Calibration to better than 0.25% of full scale is usually performed with dead weights, the only method recognized by Weights and Measures Agencies. Refer to the section on Special Installation Procedures for a discussion of the techniques available. Systems in which maximum accuracy must be achieved should be at their uniform operating temperature when calibration is performed. BLH Electronics does not recommend dead weight calibration unless required for Weights and Measures certification or where accuracy of better than ±0.25% is required.

VESSELS PARTIALLY SUPPORTED ON LOAD CELLS

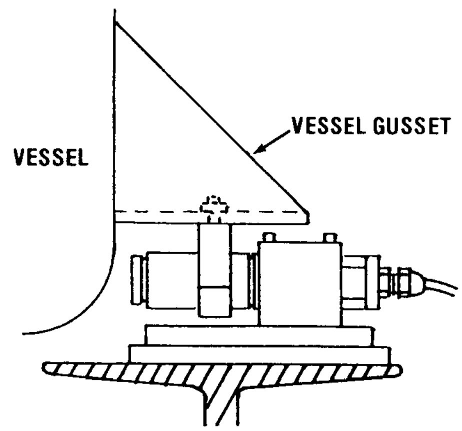
- If the main concern is repeatability, field calibration is unnecessary.
- If the weigh system accuracy must be known, then calibration by the material transfer method is required. (Dead weight calibration cannot be employed since the exact vessel center where weights would be applied is rarely precisely known or constant; i.e., a slight change in slope of the vessel causes liquid contents to accumulate toward the lower (downhill) regions, shifting the CG and, consequently, the load fraction seen by the transducers.)

Vessel restraints

Selecting KIS Beam load transducers immediately resolves the problem of vessel restraint for most applications. KIS beams are uniquely mounted such that the weigh vessel and the beam are united as one entity without undue friction or binding at the transducers. The KIS beam retainer yoke, which attaches directly to the vessel support bracket, completely encircles the beam itself. Since each beam is encircled by a retainer yoke, it is impossible for the tank to tip over. Should excessive side loading force be applied to the vessel causing an upturning moment, the vessel can only rise a fraction of an inch until the lower block of the retainer yoke contacts the underside of the beam. Only under extreme conditions, such as heavy winds on a tall storage silo, would it be necessary to consider installing safety check rods. Vessels mounted on KIS beams typically do not require stay rods. In rare situations where excessive seismic disturbance, agitation, thermal expansion, or vibration could potentially cause slippage of the retainer yoke on the beam surface, optional safety stop rings prevent the weigh vessel from sliding off the beam.



KIS BEAM VESSEL RESTRAINT, FRONT VIEW



KIS BEAM VESSEL RESTRAINT, SIDE VIEW

Accessory selection

Bearing yoke

Bearing yokes, which feature a teflon-lined bearing in the yoke assembly, are designed to allow the yoke to slide easily back and forth over the KIS beam as the weigh vessel expands and contracts. Bearing yokes are ideally suited for applications involving a great deal of thermal activity.

Dummy beams

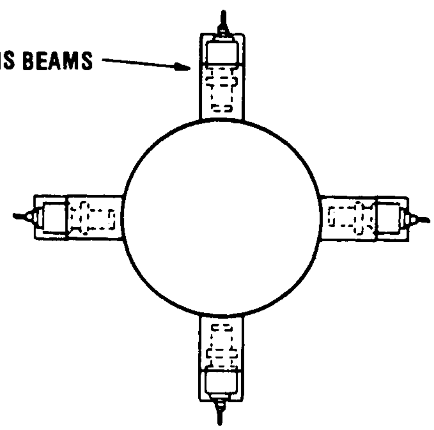
Dummy beams are used in place of KIS beams during mechanical installation procedures. Dummy beams are solid steel shafts with the same dimensions as the corresponding KIS beam. Use of a dummy beam eliminates the risk of damage to the precision KIS beam due to stray welding currents and/or mechanical impact.

KIS beam considerations

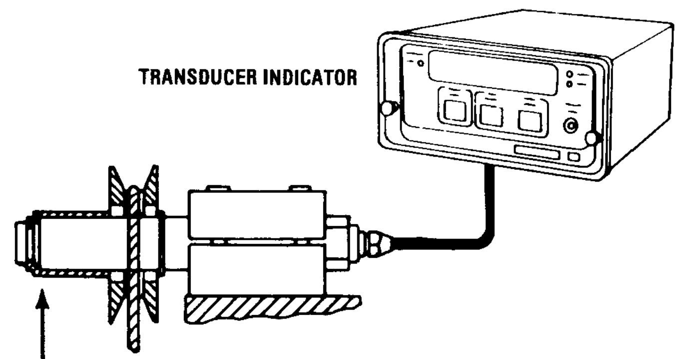
Accessory selection (continued)

Safety stop spacer

Safety stop spacers, designed to keep mounting yokes from sliding off of KIS beams under extreme circumstances, are seldom required. In conventionally designed KIS beam installations where all beams face radially inward, safety stops are not necessary. However, for exceptionally long horizontal vessels located out of doors (excessive thermal expansion and contraction), or a single KIS beam used in tension, safety stop spacers should be considered.



KIS BEAMS MOUNTED FACING RADIALLY INWARD OR OUTWARD DO NOT NEED SAFETY STOP SPACERS (SHOWN: KIS BEAMS FACING RADIALLY INWARD)



SINGLE KIS BEAM USED IN TENSION

Specific installation procedures

Preferred method - dummy beam substitution

To avoid damaging KIS beam transducers, BLH recommends that mechanical installation procedures be performed with dummy beams in place of the actual KIS transducers.

Locate and attach yokes to the vessel support brackets using two mounting holes for each yoke (use four holes when thermal insulation kits are required).

Install dummy beams in the mounting base housings.

Locate mounting base assembly, with dummy beam installed, under the yoke of each support bracket.

Level each mounting base module to within ½° (shim mounting bases as necessary) and lower the vessel onto the dummy beams.

Make certain that each yoke is making direct contact with (resting upon) its associated dummy beam. Under no circumstances should the retainer bolts be tightened so as to pull the beam upward to contact the yoke. The yoke should always be shimmed downward to contact the beam.

Using a hydraulic jack, lift vessel ⅛" only at each support bracket, and replace each dummy beam with an actual KIS Beam, one at a time. Refer to the technical manual, TM-KIS-1, for detailed instructions.

Lower the vessel gently to avoid 'shock' damage to the KIS Beam.

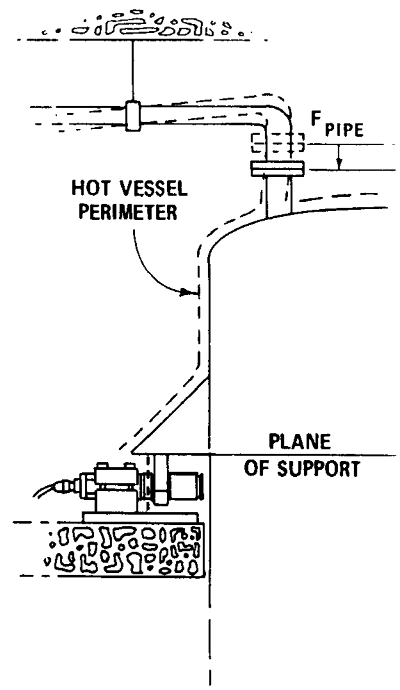
Repeat KIS Beam substitution at each vessel support bracket.

Securely fasten all retainer yoke assemblies.

KIS beam considerations

Thermal expansion or contraction

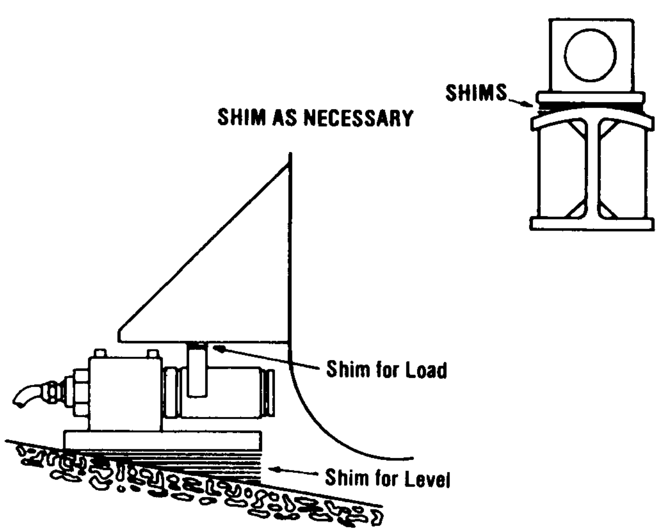
When application conditions suggest that vessel expansion or contraction, due to thermal forces, will be a standard feature of the overall process, bearing yokes should be installed at each vessel support bracket. Bearing yokes contain a teflon-lined bearing which allows the yoke to slide easily along the surface of the KIS beam. Slight yoke displacement from the recommended beam load point will not greatly affect the system accuracy or repeatability, as each millimeter of displacement yields only a 0.005% change in calibration. Bearing yokes should be considered if the vessel is to be mounted out of doors or if the vessel will be used at a temperature other than ambient.



Load distribution for KIS beams

- **Shim mounting base (first)**

Once the correct mounting location has been determined for the base assembly, metal shims must be used to level the assembly in both length and width. Stagger shims or shim segments between the base assembly and the mounting support, as shown in the illustration below. Tighten securely and check that the base and beam assembly is plumb within ½°. The side to side level is not critical since the KIS Beam can be rotated in the housing to coincide with the load direction. Do not disturb the base assembly after it is plumb.



- **Shim for load distribution**

With empty vessel weight resting on the KIS beams, measure the output of each beam with a readout instrument such as a BLH Model 352B Transducer Indicator. Each beam must indicate some output representing partial weight of the empty vessel. Normally, readings should be from 1 to 10mVdc. No beam should indicate less than 10% of the empty vessel weight; ideally each beam would indicate a proportionate share. Any beam outputting less than 10% of the vessel weight must be shimmed between the yoke and vessel mounting point. If a gap exists between the yoke and KIS beam, determine the gap size, raise the vessel, loosen the yoke mounting bolts, and add shim material equal to the measured gap plus .015 to .030 inches. If no gap was measured between the beam and the yoke, yet a low output was measured, insert a trial shim of .015 to .030 inches and recheck all beams for proper weight distribution. Repeat this shimming measurement procedure until all beam outputs read within 20% of each other.

load cell considerations

Lateral restraints — stay rods, safety check rods

LATERAL RESTRAINTS are mechanical devices designed to secure a weigh vessel to the structure, thereby maintaining 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, employing it would be detrimental to weigh system accuracy. So, with few exceptions, it is advisable to apply some form of restraints to all weigh vessels for reasons of...

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.

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

PARTIAL LISTING OF OPERATIONAL AND ENVIRONMENTAL ELEMENTS ACTING TO DISTURB A VESSEL...

INTERNAL TO VESSEL:

- fluid sloshing
- violent chemical reactions
- material entry and exit (thrust and impact forces due to mass flow)

EXTERNAL TO VESSEL:

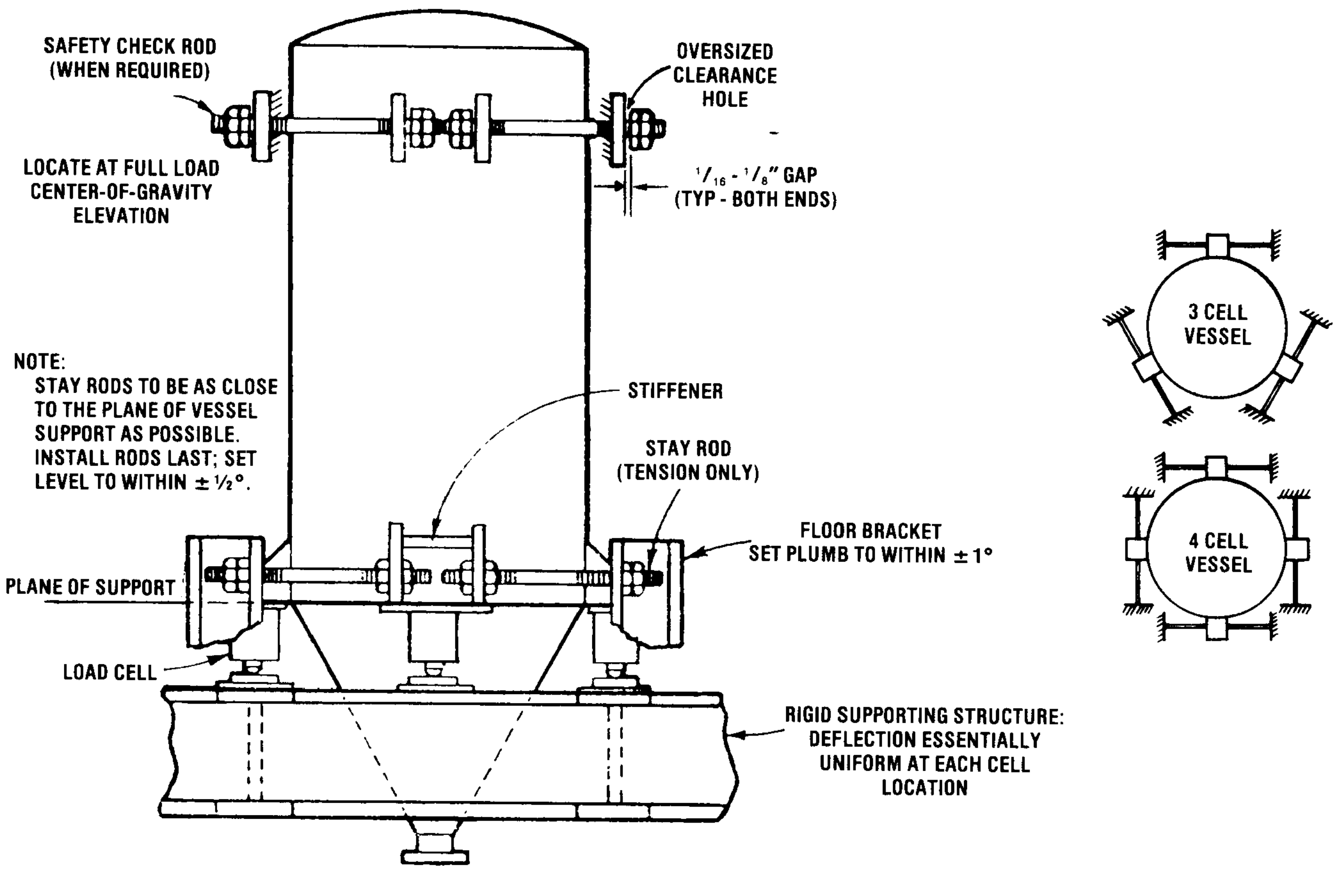
- vibrators or live bottoms
- agitators
- thermal expansion of attached piping
- structural support vibration from rotating equipment or traffic
- structural support deflection from adjacent vessels, equipment or traffic
- potential impact from traffic or overhead crane
- wind
- seismic events
- other expected events

STAY RODS, SAFETY CHECK RODS - Experience has shown the use of tension straps to be a simple, but 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 tangential to, the vessel. BLH Electronics defines two categories of tension straps...

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 ensure a linear response with deflection. Rules for sizing stay rods are presented in the BLH publication entitled 'TECHNICAL DATA/Sizing of Lateral Restraints' (TD 068).

SAFETY CHECK RODS are backup members whose sole function is to hold the vessel in "check", preventing gross tipping or wobbling. These straps are installed with a loose fit so that they do not interact with the weigh vessel even after thermal growth, but simply contribute to the vessel tare weight. Safety check rods may be 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.

Lateral restraints — stay rods, safety check rods (continued)



TYPICAL ROD ARRANGEMENT

STAY ROD installation considerations:

By terminating the rods at brackets adjacent to the vessel and separate from the building structure, the rod end deflection is effectively limited to the load cell compression (0.010") or tension linkage elongation (0.030") rather than the much greater overall floor deflection between the vessel and structure. 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 of the disturbing forces (e.g., seismic or wind) act at or near this location. In this case, 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, enhancing access to the vessel.

load cell considerations

Lateral restraints — stay rods, safety check rods (continued)

LATERAL RESTRAINTS are not necessary for vessels that meet all requirements listed:

Essentially static contents; no significant agitation or vibration.

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

Three or more supports.

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

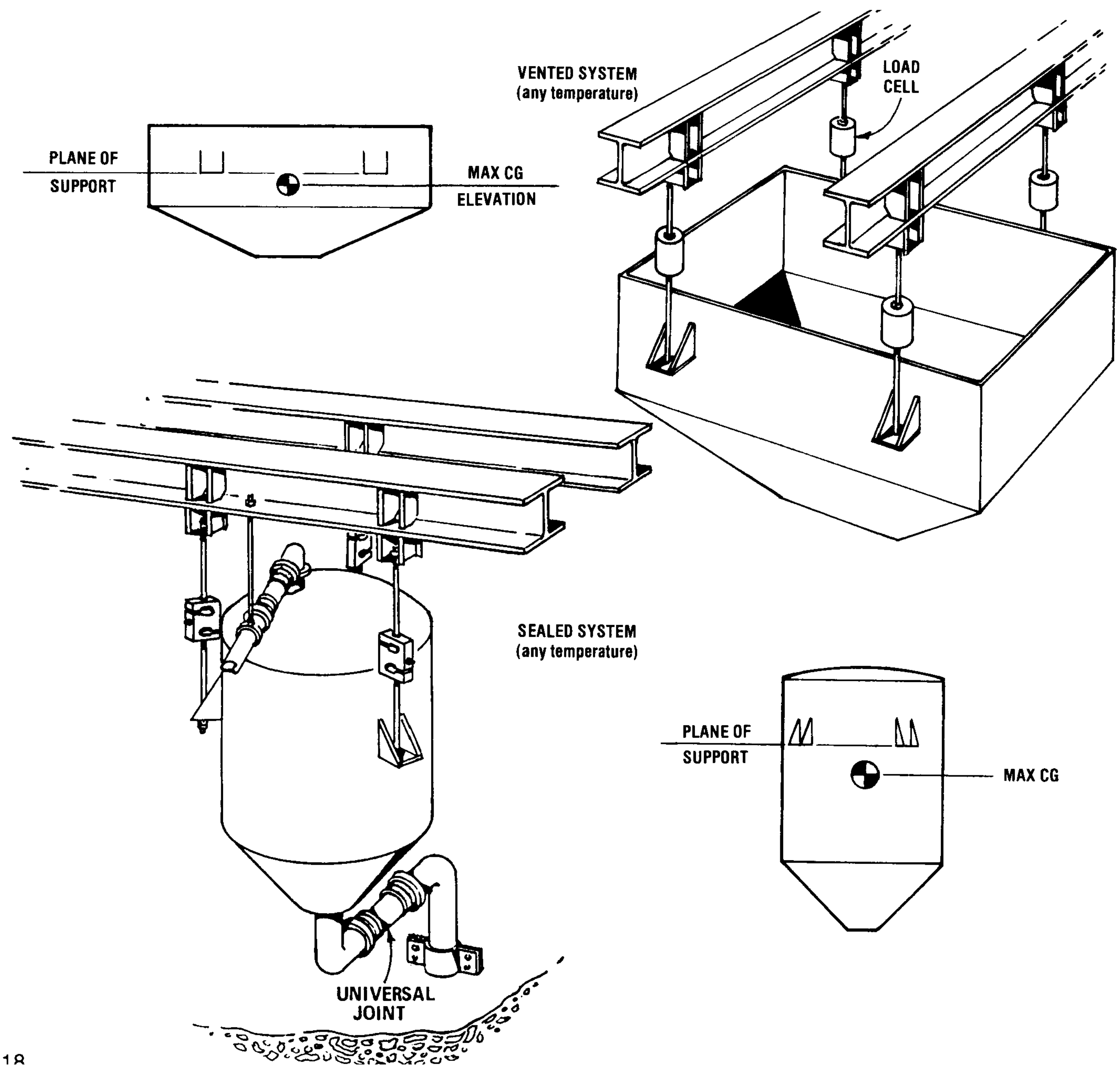
Either no direct piping contact (vented systems) or only very flexible nonmetallic connections (sealed systems). Refer to "Piping Design" section for suggestions.

Slow material flow rates (sealed systems).

Mounted in tension or rest on fixed mounting plates.

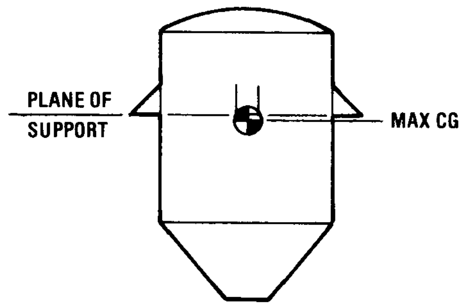
OBSERVATION:

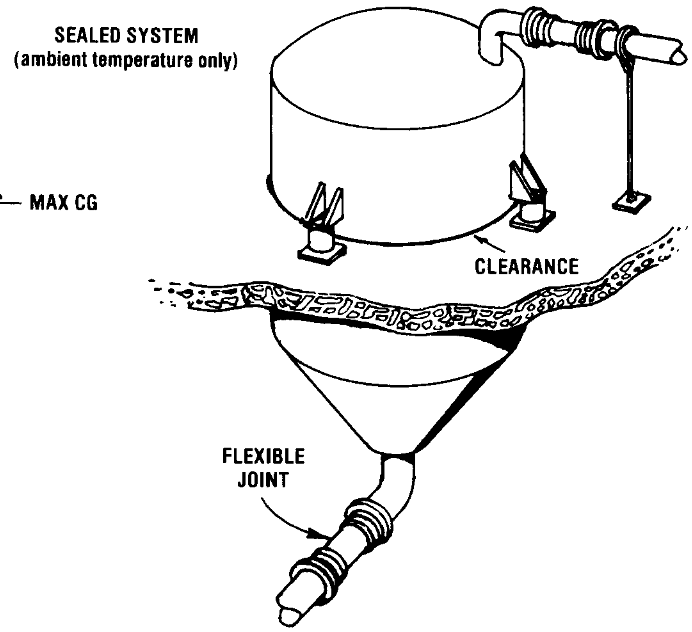
Should minor disturbances be present or expected, safety check rods or some form of bumper may be added to preclude large vessel motion. This is possible only for vessels that will return to their original position after the disturbance is over; e.g., vessels supported in tension or compression at or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



Lateral restraints — stay rods, safety check rods (continued)

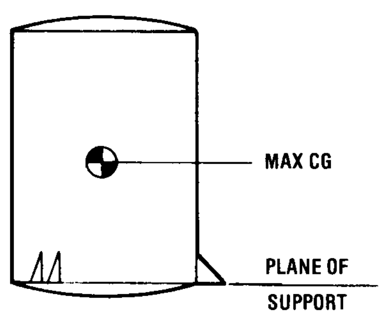
LATERAL RESTRAINTS not necessary for vessels meeting all requirements listed on Page 18.

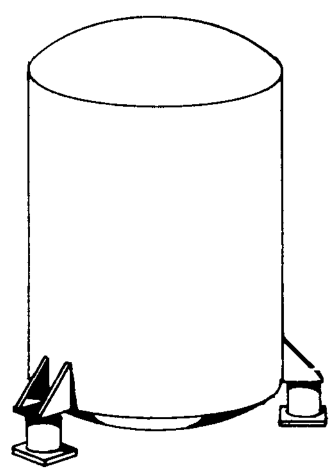




Special Case: Vessel center-of-gravity above plane of support

Storage vessel off in a corner, totally undisturbed, contents nonhazardous





LATERAL RESTRAINTS are essential for vessels subjected to one or more of the following:

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

Very active contents; sloshing or violent chemical reaction.

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

Large agitator or vibrator (Refer to "Special Applications" section for suggestions on vessels with vibrators).

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

Top heavy or heavy off-centered auxiliary equipment.

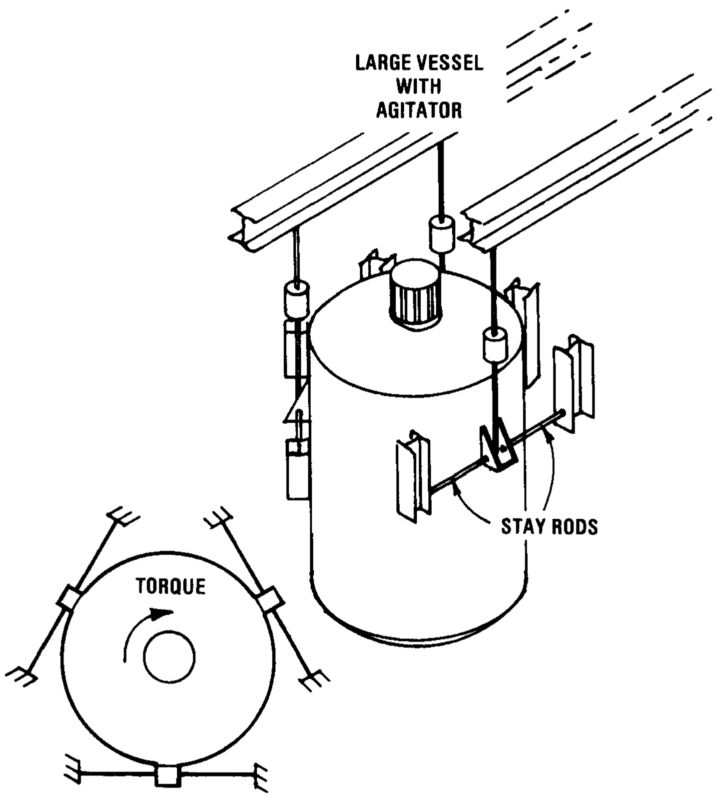
OBSERVATION:

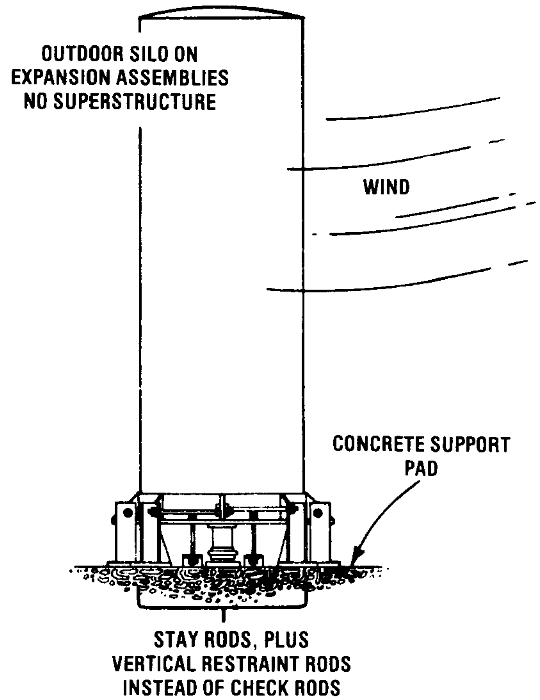
When the significance of disturbing forces is uncertain, it is good practice to design the restraint system, provide attachment points on the vessel, and then see how the vessel functions in operation. If restraints are required, the space should be available and the restraints can then be added.

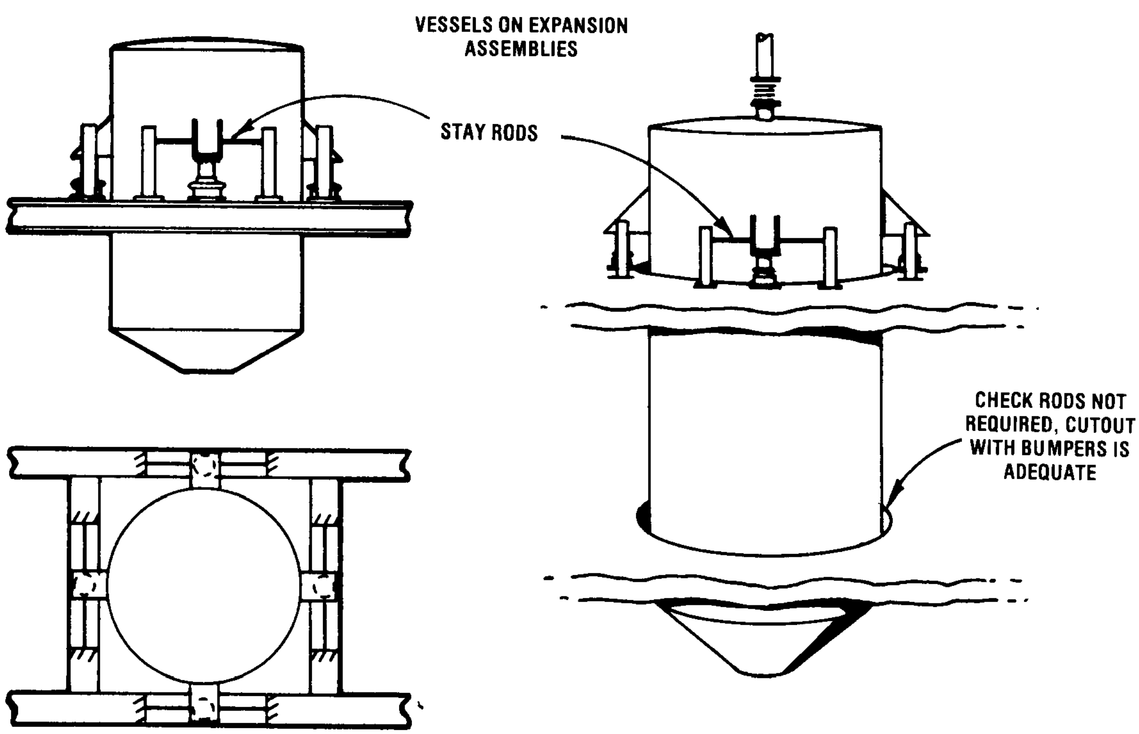
load cell considerations

Lateral restraints — stay rods, safety check rods (continued)

LATERAL RESTRAINTS are essential for vessels subjected to one or more of the factors listed on Page 19.

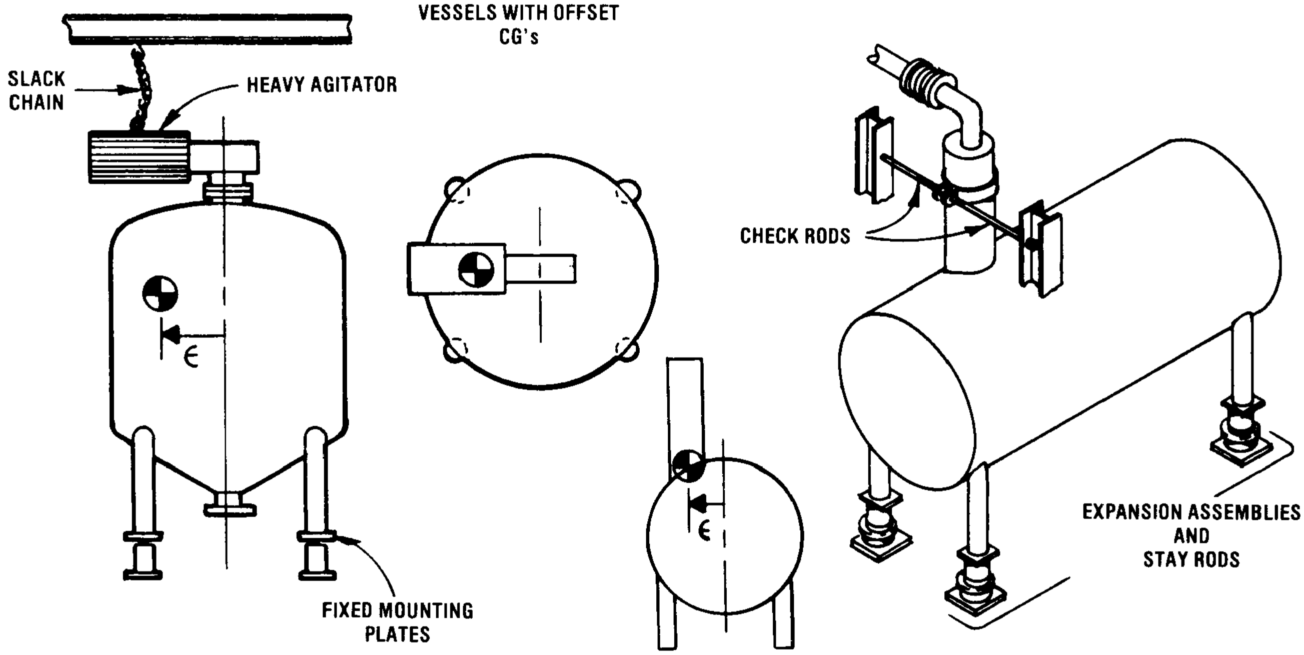


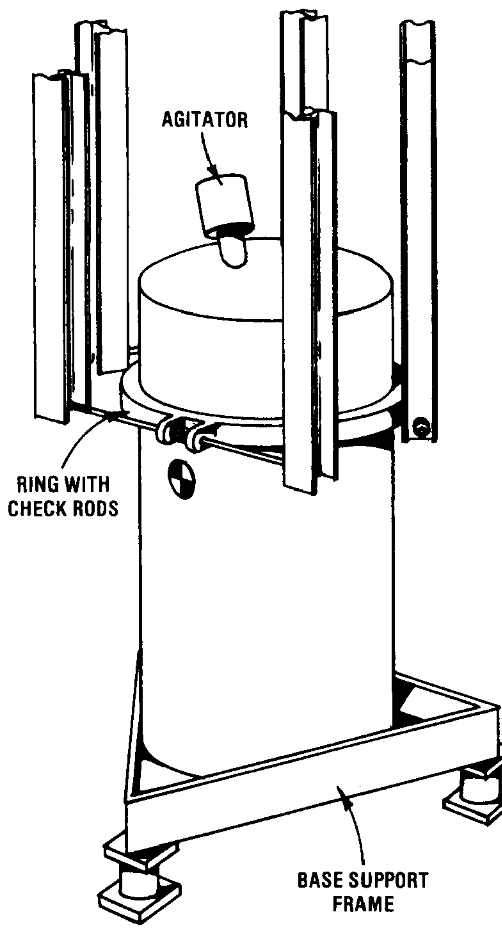


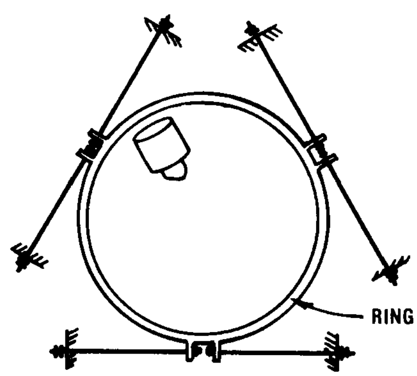


Lateral restraints — stay rods, safety check rods (continued)

LATERAL RESTRAINTS are essential for vessels subjected to one or more of the factors listed on Page 19.



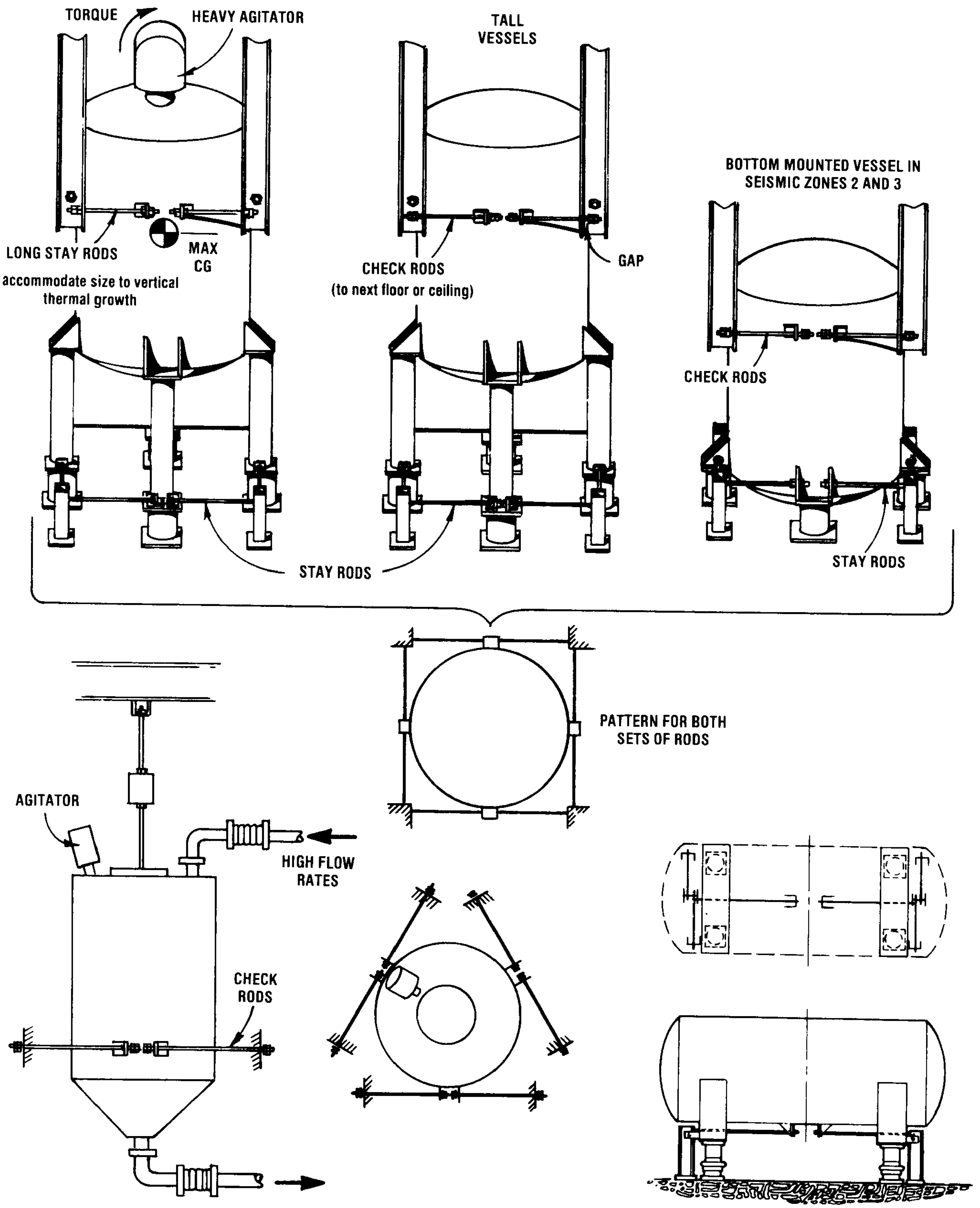




load cell considerations

Lateral restraints — stay rods, safety check rods (continued)

LATERAL RESTRAINTS are essential for vessels subjected to one or more of the factors listed on Page 19.

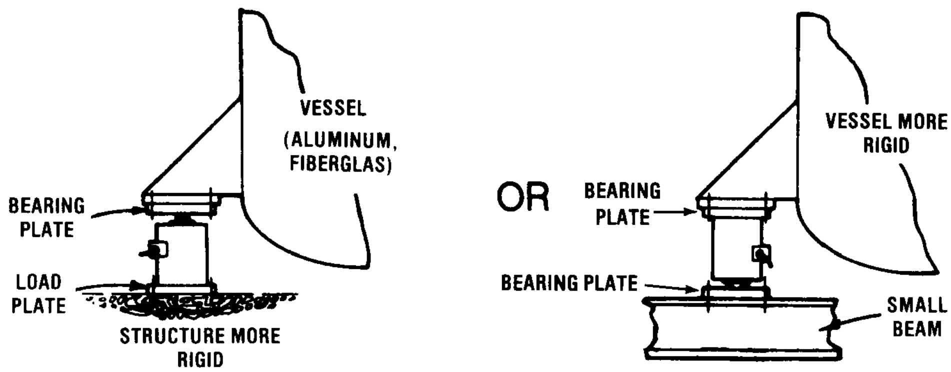


Load cells in compression

General rule for compression use

Attach load cell to whichever surface is more rigid, the vessel support bracket or supporting structure. The load cell should not deviate from initial plumb during service, or calibration accuracy may be compromised. When the choice is not apparent, mount load cell with load button down.

Fixed mounting plates



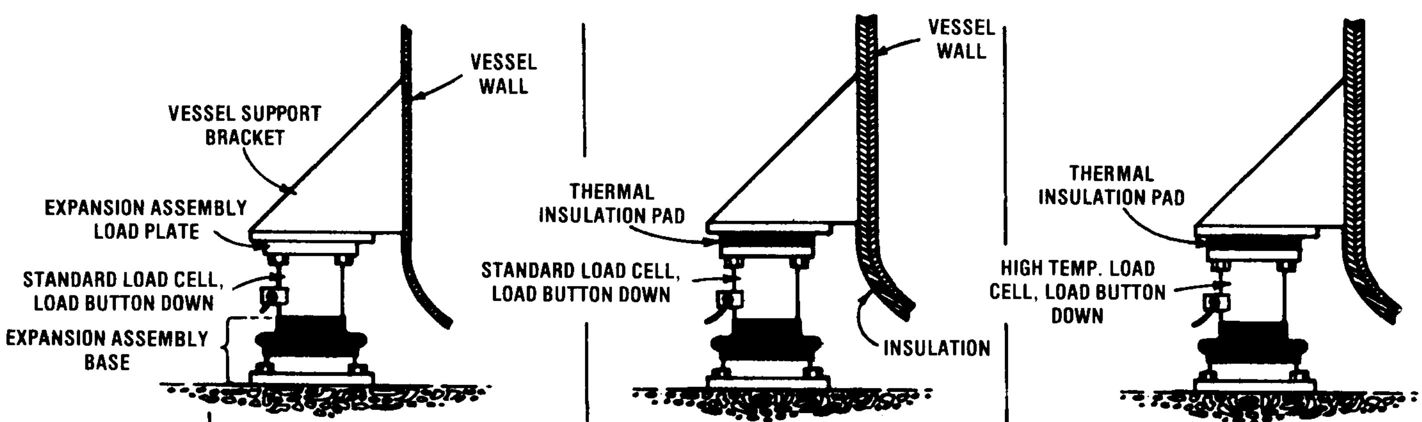
Standard mounting kit when vessel and support structure are both at ambient temperature and are of the same material.

Expansion assembly

Accommodates thermal expansion or contraction of a vessel relative to support structure with minimum sideloading of load cell. Generally necessary outdoors and indoors when vessel temperature differs from ambient. The load cell is usually installed with load button down for convenience.

Thermal insulation pad

Reduces heat conduction from heated vessel to load cell allowing load cell temperature to remain close to ambient; temperature effects on performance are thus minimized and calibration accuracy is preserved. The pad is made of a rigid glass-cloth laminate with extremely low thermal conductivity.



VESSEL TEMP.	To 130°F	Above 130°F	Above 130°F
AMBIENT TEMP.	To 130°F	To 130°F	130°F To 425°F

load cell considerations accessory selection and installation

Load cells in compression (continued)

Installation tools

These "simulated" assemblies duplicate the critical dimensions of the corresponding load cells and accessories for use in place of load cells during vessel installation. Eliminates risk of damage to precision load cells due to stray welding currents and mechanical impact.

HOW TO USE

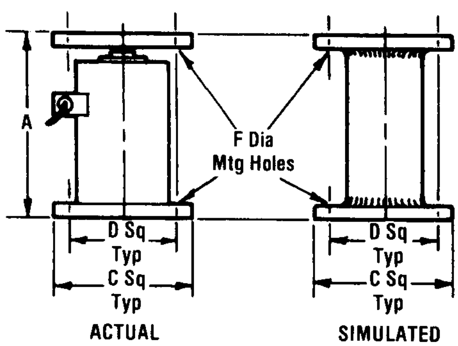
Order simulated assemblies when placing load cell order for delivery in advance of load cells.

Install simulated assemblies; make all piping connections, weld, insulate, etc.

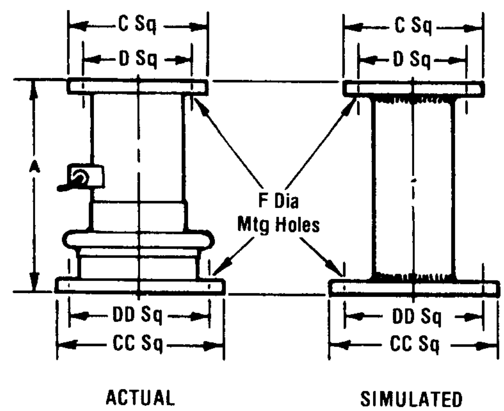
When vessel work is complete, jack each vessel support ⅛", remove simulated assembly, replace with load cell and accessory, and gently lower vessel.

Shim as required to plumb load cells and equalize tare weight among the cells.

Simulated load cell and fixed mounting plates

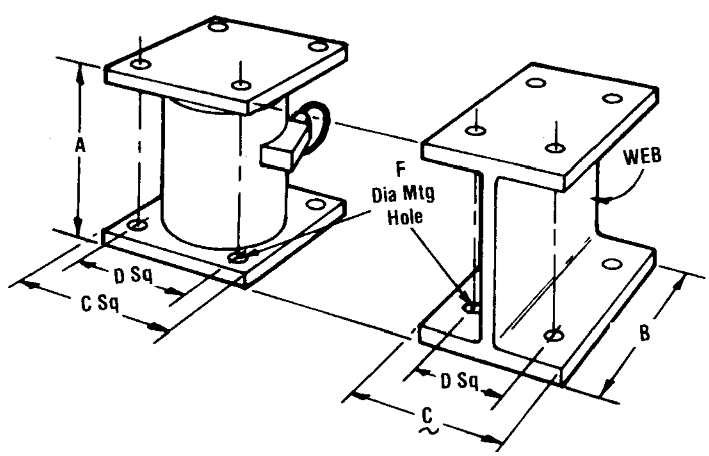


Simulated load cell and expansion assemblies

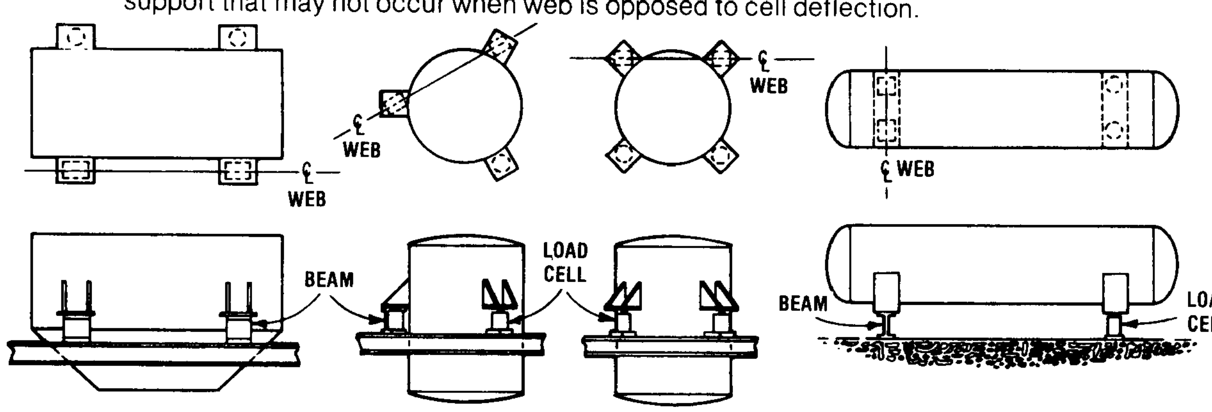


Flexure beams

Flexure beams can be substituted for load cells and fixed mounting plates in lower accuracy weigh systems. Flexure beams are generally used for nonagitated vessels containing self-leveling materials, operating at constant ambient temperature.



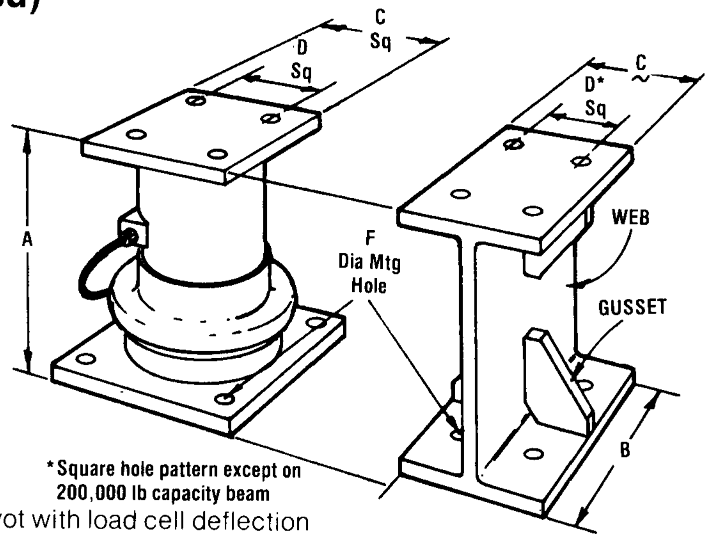
APPLICATIONS: Align beam webs so vessel can pivot with load cell deflection, thus providing a flexibility to vessel support that may not occur when web is opposed to cell deflection.



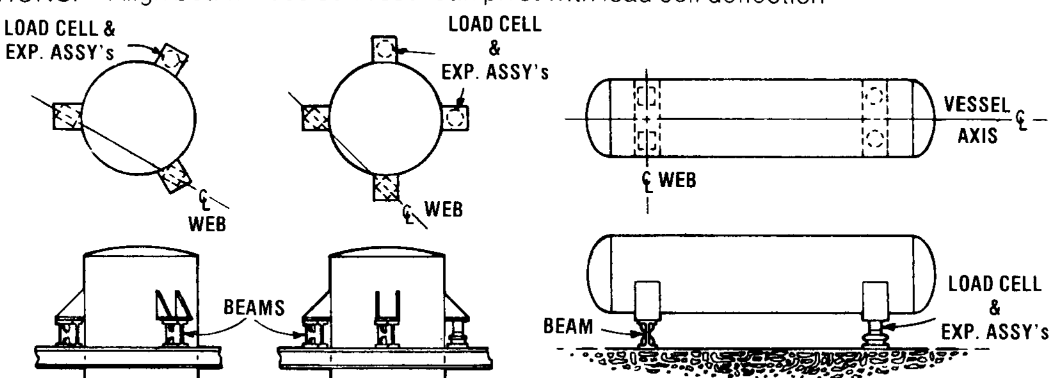
Load cells in compression (continued)

Bearing Beams

Bearing beams, substituted for load cells and expansion assemblies in lower accuracy weigh systems, are generally used on vessels containing self-leveling materials with no agitation. Since gussets are required to preclude buckling of the beam web, negligible beam motion occurs under vessel expansion: all vessel growth must be accommodated by the expansion assembly.



APPLICATIONS: Align beam webs so vessel can pivot with load cell deflection

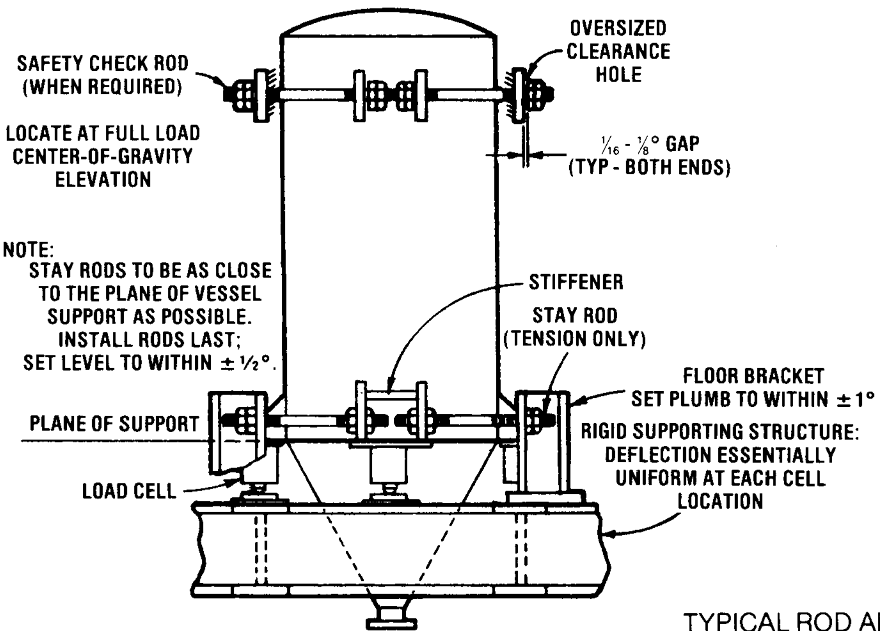


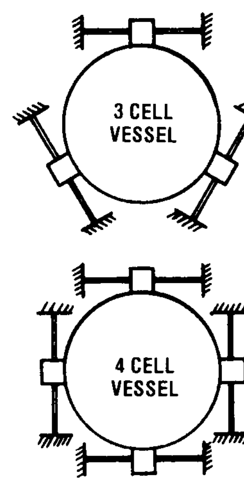
Stay rods

Stay rods provide positive lateral restraint for vessels with agitators or vibrators; hold vessel centered on expansion assemblies so full design travel is assured. Since stay rods are an active part of the weigh system, install level to ensure a linear response with deflection.

Safety check rods

Safety check rods provide back-up restraint capability for unlikely events — high wind, seismic, wayward fork-lift, etc — when vessel center-of-gravity is above support plane (and stay rods). Check rods are normally passive members, adding only to the tare weight of the vessel.





TYPICAL ROD ARRANGEMENT

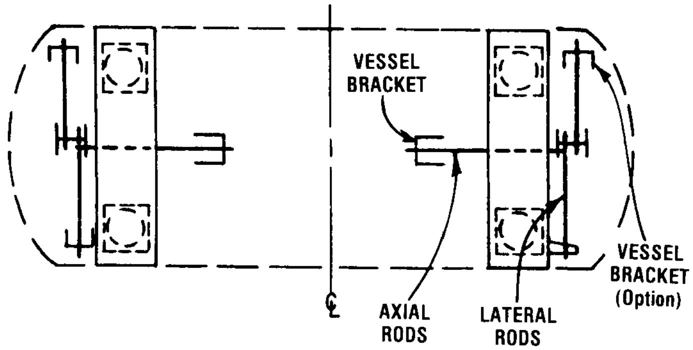
load cell considerations accessory selection and installation

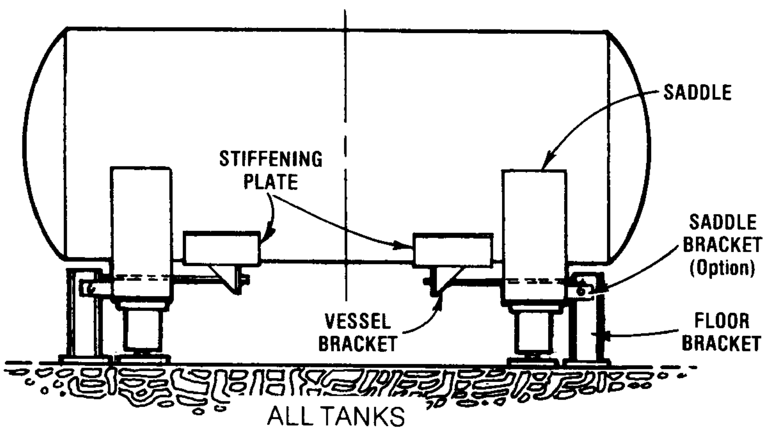
Load cells in compression (continued)

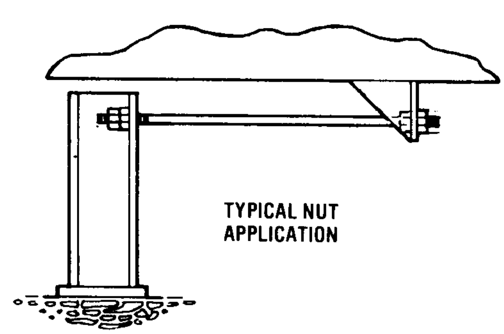
Stay rods for horizontal tanks on load cells and fixed mounting plates

General rule:

Locate lateral rods close to the ends of tank for maximum leverage against piping moments tending to rotate the tanks.



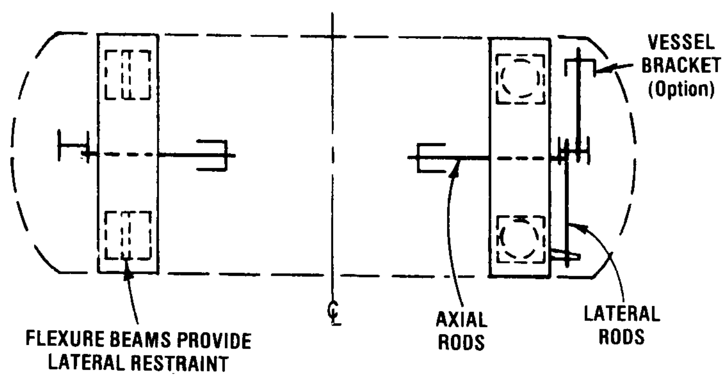


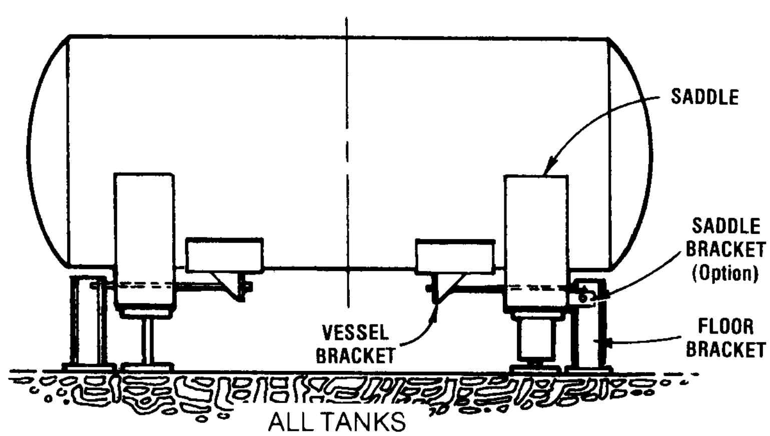


Stay rods for horizontal tanks on load cells and flexure beams

General rule:

Locate lateral rods close to ends of tank for maximum leverage against piping moments tending to rotate the tanks.





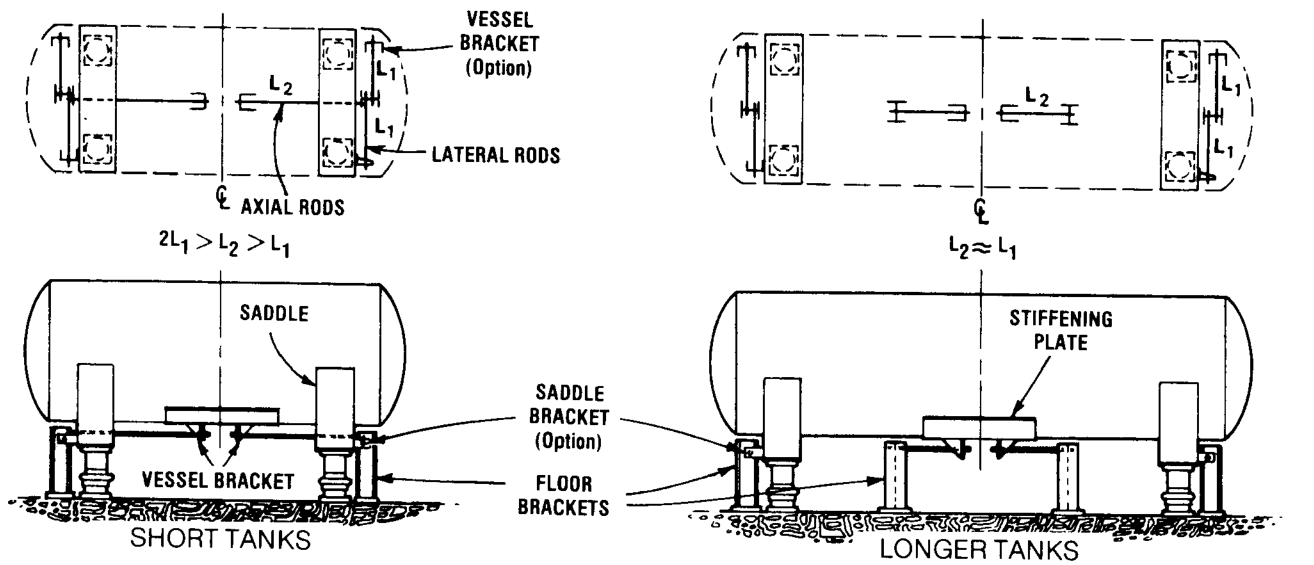
Load cells in compression (continued)

Stay rods for horizontal tanks on load cells and expansion assemblies

General rules:

Locate lateral rods close to ends of tanks for maximum leverage against piping moments tending to rotate the tanks. (Leave room for vessel expansion between floor bracket and saddle.)

Locate vessel-mounted axial restraint brackets close to tank center to minimize slackening of stay rod due to tank thermal expansion. (On longer tanks, axial rods extending all the way to the lateral rod brackets can not be used due to excessive rod elongation under load.)

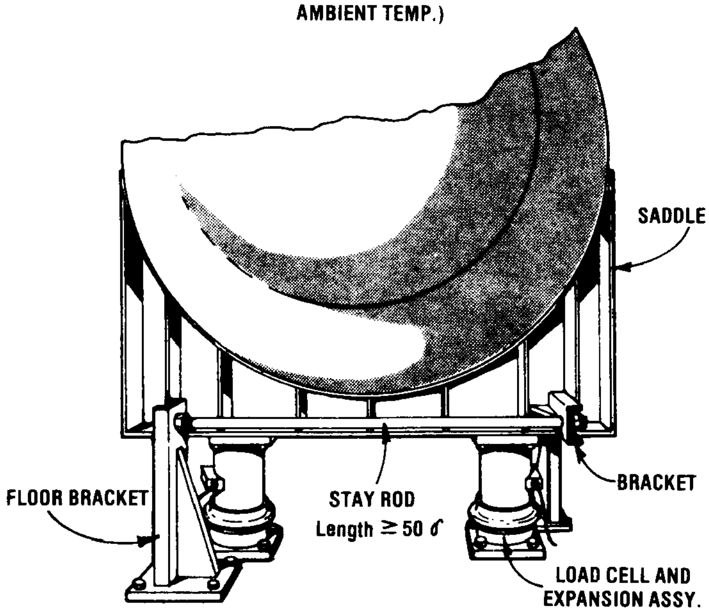


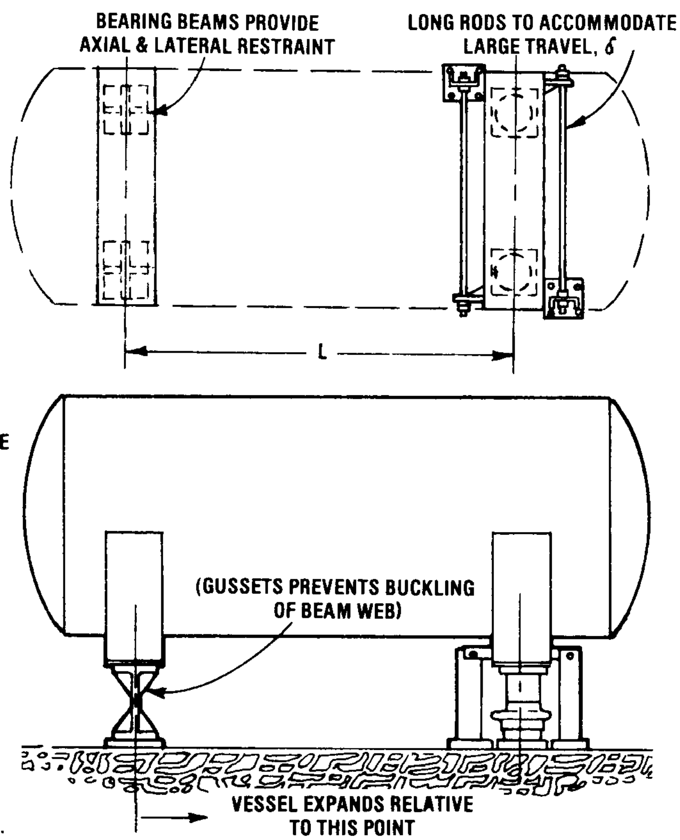
Stay rods for horizontal tanks on load cells and bearing beams

ESTIMATE TRAVEL, $\delta = L \alpha \Delta T$

WHERE, α = COEFFICIENT OF THERMAL EXPANSION

ΔT = MAX. TEMP. DIFFERENCE BETWEEN VESSEL AND SUPPORT STRUCTURE = (MAX. VESSEL OPERATING TEMP. — MIN. AMBIENT TEMP.)

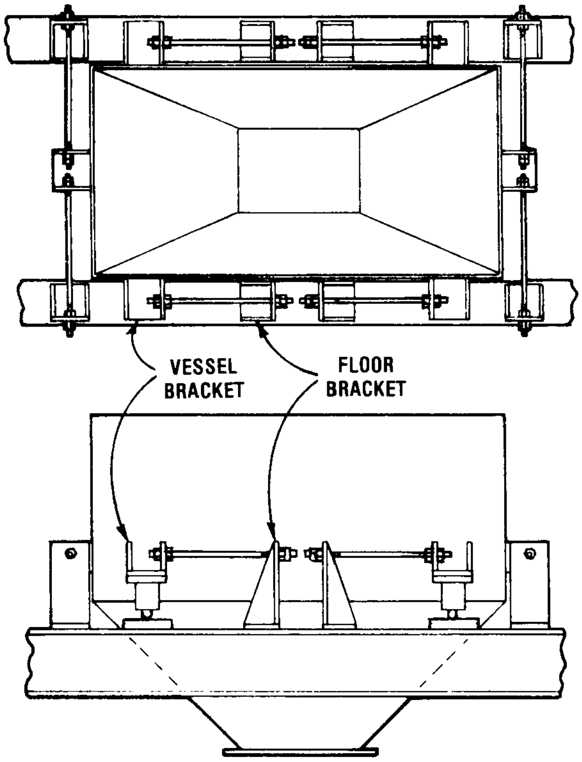


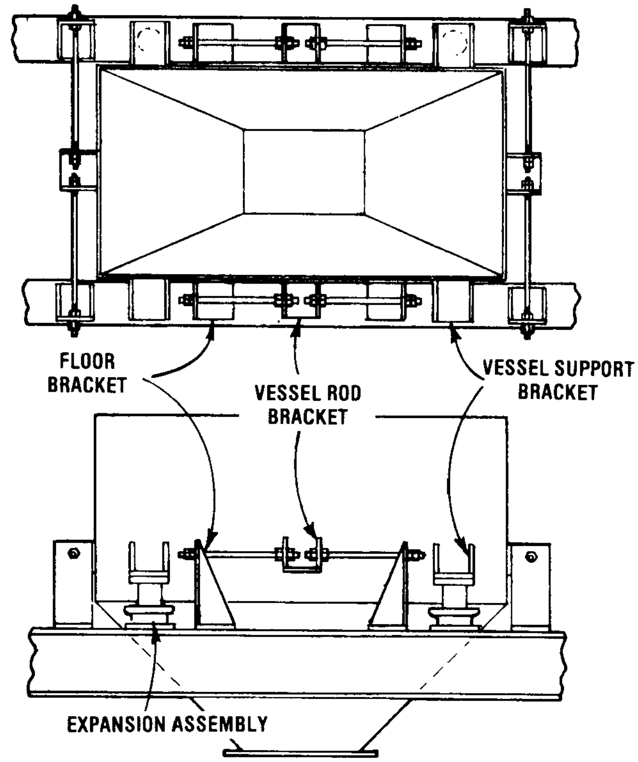


load cell considerations accessory selection and installation

Load cells in compression (continued)

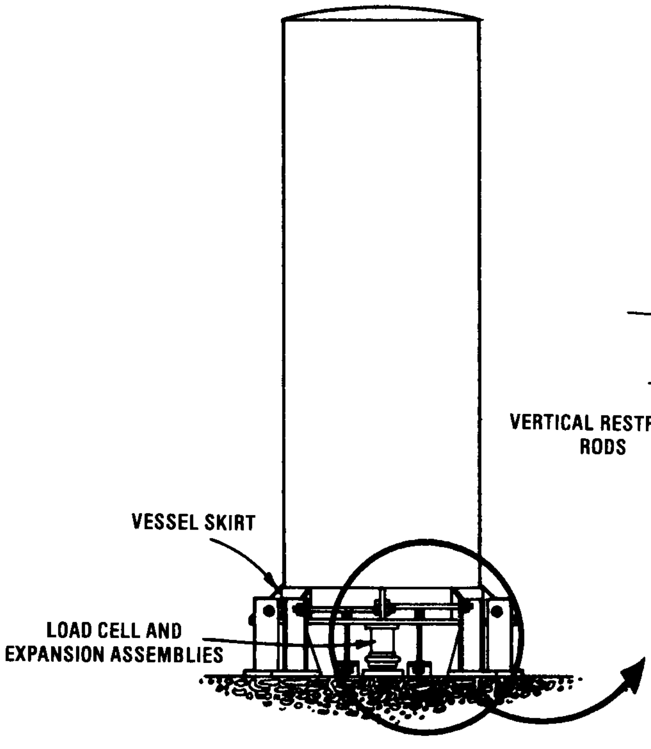
Stay rods for hoppers and bins, any temperature

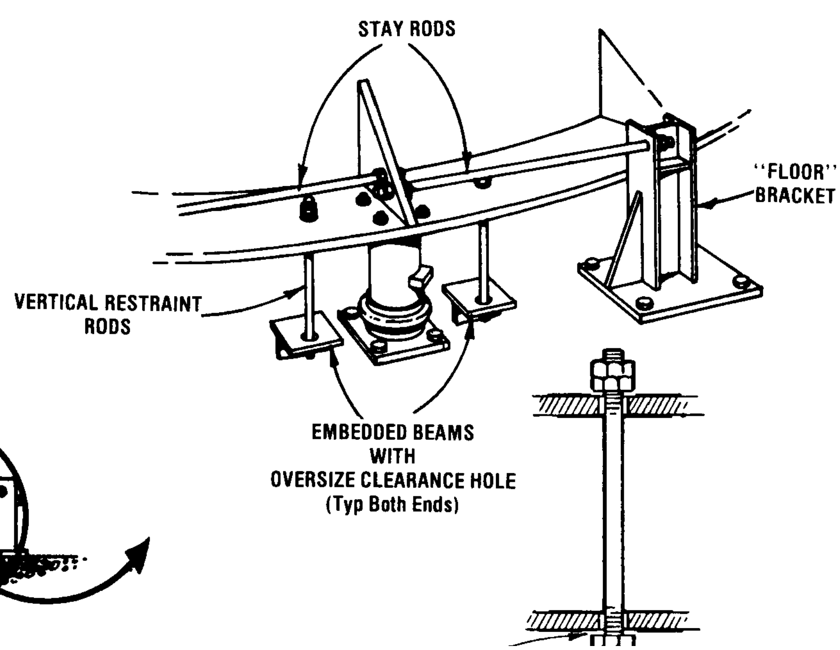




Stay rods and vertical restraint rods for tall outdoor vessels without surrounding structure

When tall vessels must be protected against tipping due to wind or seismic forces and safety check rods are impractical, use "vertical restraint rods" (loose-fitting check rods) at the base of the vessel as shown. The vertical restraint rod must not be tightened since this would load the load cell and possibly damage the load cell if overloaded.





Load and S-cells in tension

Tension flexure rods

Tension flexure rods are used to suspend weigh vessels from overhead structure. Preferred for heated vessels over compression arrangements since sideloading is all but eliminated. Chief deterrent is the cost of support structure, which effectively limits cell capacity to 50,000 lbs. A minor consideration is increased vessel displacement and vibration sensitivity due to rod elongation with load.

General design rules:

1. Overall length between support surfaces, **S** must be larger than either:
   a. The length which holds the maximum change in initial load/S-cell plumb due to differential thermal expansion between vessel and support structure to within ¼ degree. (This renders changes in calibration accuracy due to "Cosine Error" trivial.) Calculate this minimum length as:

   $$S\ min = 230R\alpha\Delta T$$

   WHERE **R** = Distance between support point on vessel bracket and centerline of vessel

   α = Coefficient of thermal expansion of the vessel

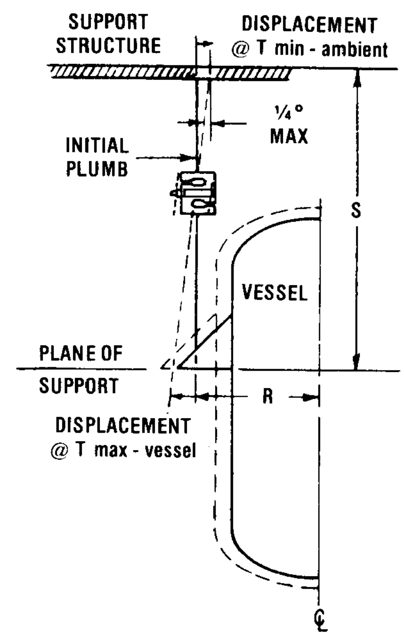
   ΔT = Max. temperature difference between vessel and supporting structure, usually taken as max. vessel operating temperature less min. ambient temperature

   b. The length which from BLH experience, imparts the required degree of flexibility to the tension linkage. **S min** ranges from 20 inches for a 50 lb load/S-cell to 40 inches for a 50,000 lb cell.

   EXAMPLE: An eight foot diameter stainless vessel operates at 470° in an ambient environment at 70°F. Taking **R** to be about 56", **S** ≥ 50".

2. Optimum load /S-cell placement is midway between support points. Doing this minimizes readout error due to moments acting across the cell.

3. Request BLH Electronics Data Sheet entitled "Technical Data for Calculating Rod Lengths" (TD-063) for detailed instructions and ordering information.



NOTE: FOR LOWER ACCURACY SYSTEMS S MAY BE REDUCED TO 75% OF THE MINIMUM VALUE

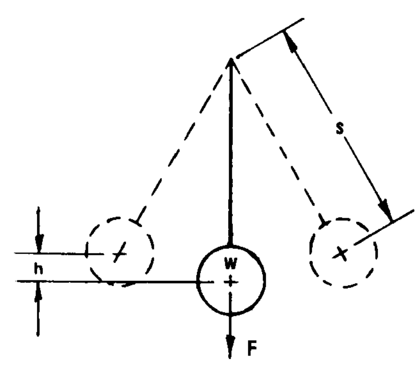
Errors due to swaying

When vessels are suspended, care must be taken that the amount of swaying is limited. These errors, often small in weigh vessels, can be substantial in crane scales. The error is introduced due to the centrifugal force generated when the weight moves through the bottom of its arc, similiar to the pendulum in a clock. The frequency of the acceleration force is therefore twice the pendulum frequency or

$$fr = 2 \times \frac{1}{2\pi}\sqrt{\frac{g}{s}}$$

where g is the gravity constant. The centrifugal force is proportional to the increase in height of the weight.

$$F = w\frac{h}{s}$$



load cell considerations
specific installation procedures

Installation sequence for compression load cells

- **Preferred method - recommended for High Accuracy Systems**

Fabricate, or order from BLH Electronics, Simulated Load Cells and Fixed Mounting Plates or Simulated Load Cells and Expansion Assemblies. Bolt to vessel support bracket.

Lower vessel in place and align.

Using lower Simulated Assembly flange as a template, drill mounting holes in mating support structure, and bolt securely.

Install lateral restraints, if required, to maintain vessel alignment for all subsequent operations.

Complete vessel fabrication and installation. Make all piping connections, weld, insulate, etc.

Loosen and remove all lower flange bolts.

Using a hydraulic jack, lift vessel ⅛" only at each bracket, one at a time. Remove Simulated Assembly; install load cell; shim plumb to within ½°; install accessory (bearing plate, expansion assembly base, etc).

LOWER VESSEL GENTLY to avoid overload damage to load cell.

Repeat load cell installation operation at each bracket.

Loosen all stay rods to remove any possible restraint, recheck level to within ½°, and secure snugtight.

When done, check load distribution among the cells, shimming if necessary.

- **Alternate method - suitable for Lower Accuracy Systems**

Install lateral restraints, if required. Set level within ½°.

Bolt load cells in place; visually check load cell plumb, shimming if necessary; install accessory.

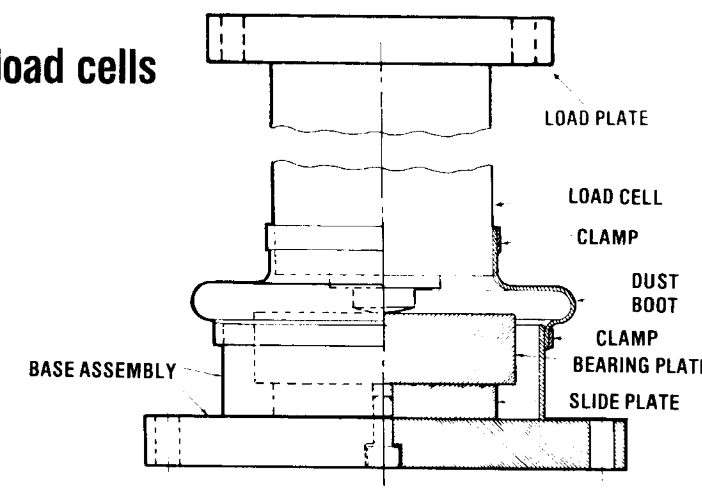
LOWER VESSEL GENTLY onto load cells.

Check load distribution among cells, shimming as required.

Expansion assemblies for compression load cells

Expansion Assemblies accommodate thermal expansion or contraction of a vessel relative to support structure with minimum side loading of the load cell. They are generally necessary outdoors when maximum accuracy is desired or indoors when the vessel temperature differs from ambient. An Expansion Assembly includes a low friction slide plate in the "base assembly", a "load plate", and the appropriate load cell mounting screw(s).

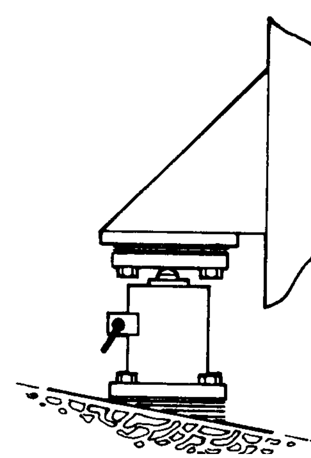
For details, refer to instructions shipped with unit.



Load distribution for compression load cells

- **Shim load cells plumb (first)**

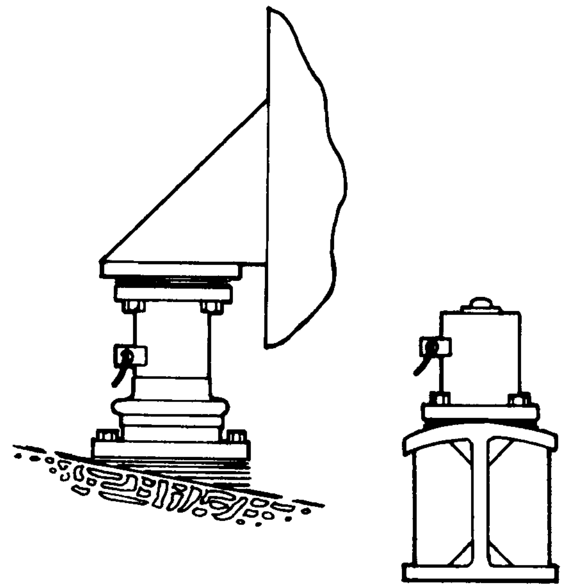
Stagger shims or shim segments between the load plate and support, as shown in sketches (at right and on next page). Tighten securely and check that cell is now plumb within ½°. Repeat procedure until plumb. Do not disturb the load cell thereafter.



Load distribution for compression load cells (continued)

- **Shim for load distribution**

With full tare weight resting on load cells, measure output of each cell with a readout instrument such as a BLH Model 352B Transducer Indicator or equivalent. Each cell must indicate some load, preferably not less than 10% of tare weight. If any cell indicates "no" output during this test, use a feeler gage to measure gap between load button of cell and bearing plate (or mating accessory), raise vessel, unfasten bearing plate, and insert a trial shim having a thickness of 0.015 - 0.030 inches plus the gap height. Similarly, if a cell indicates "low" output, insert a 0.015 - 0.030 inch trial shim. Secure bearing plate and GENTLY LOWER weighed structure onto load cells. Since adjustment at one load cell alters load distribution at all support points, measure the output of each load cell again. Repeat this shimming measurement procedure until all load cells read within 20% of each other.



system calibration

BLH Electronics offers field calibration services as part of its complete weigh system commitment. Field engineers will travel to the site and perform the following operations:

- **Field calibration procedure**

  Visually check load transducer plumb and accessory installation. Correct if necessary.

  Visually survey vessel and all attachments for at least ½" clear space all around. Enlarge any tight clearances that have potential for near term or long term shifting and mechanical hangup.

  Measure load distribution on load transducers supporting weigh vessel with a BLH Model 352B Transducer Indicator or equivalent. Shim as required to ensure that the tare weight is distributed on each load transducer to within 10% of each other transducer. (Refer to the Sections on Load Distribution for complete instructions).

  Calibrate weigh system electronically using a BLH Model 625 Precision Calibrator or equivalent.

  Inspect lateral restraint system (stay rods and safety check rods) for proper installation and attached piping for flexibility consistent with required system accuracy. Make recommendations for improved system performance based upon experience with similar installations.

  When required, arrange for and perform the appropriate mechanical (dead weight) calibration.

- **Electronic - provides calibration accuracy to 0.25% of full scale**

  Compensates for initial load cell installation misalignments such as load cells out of plumb. Does not compensate for any mechanical errors that might arise during vessel operation such as load transducer losing plumb due to beam deflection or twist, nonlinear piping reactions, highly tensioned lateral restraints, or thermal expansion. Rather, the weigh vessel is assumed to be free from mechanical restrictions. If attached piping can be felt to move under a sharp blow of the fist, the assumption is usually valid.

  Procedure: One load transducer in the weigh system is electrically replaced with a precise signal from a BLH Model 625 Precision Calibrator. The Calibrator is a device which simulates the output of the load transducer. System calibration is then performed with all cables in place, under actual environmental conditions.

  The Model 625 Calibrator is accurate to within 0.05% of reading, or 0.02% of range, whichever is greater.

- **Mechanical - provides calibration accuracy to better than 0.25% of full scale depending upon method and care used. Of methods listed below, only Dead Weight and Dead Weight/Material Substitution are accepted by Weights and Measures Agencies.**

  Compensates for initial load cell misalignments.

  Shows up mechanical errors which may be at least partially compensated for by adjustments within the system instrumentation. Depending upon system accuracy requirements and severity of the problem, mechanical corrections to piping attachments, lateral restraints, or support structure may have to be performed.

  Usually preceded by electronic substitution to ready system for fine tuning with dead weight.

  Requires use of weight increments of not less than 5% of live load. When certification is necessary, with stringent tolerances given as a percent of test load, increments should not be less than 10% of live load.

  Note that span cannot be set with the first increment of weight as for mechanical scales, since a one-count error at 5% of load may be 20 counts out at full load. On lower accuracy systems, span may be set at 25% of load, since maximum error is then only four counts.

  "Warm Body" method

  Simplest and quickest to perform.

  Suitable for calibration of low capacity weigh vessels only; i.e., up to about 2,000 lbs.

  Procedure: Weigh several men on best available scales at hand, e.g., 0.1% shipping room scales, and have them sequentially climb upon weigh vessel.

  Calibrated Material Transfer method

  Accuracy obtainable strictly dependent upon care taken in weighing the test material. For example, a tank truck may be weighed empty on a 0.1% truck scale, then filled with test material and re-weighed. But how much gasoline was consumed in the drives between weighing or in the final drive to the site? Did the driver stay in the truck during both weighings? How much material was lost in the transfer from truck to weigh

Calibrated Material Transfer method (continued)

vessel? If a water meter is used, do you believe its reading or recalibrate it on site using a 55 gallon drum and the 0.1% shipping room scale?

Procedure: Add pre-weighed test material (either product or material inert to vessel, such as water, sand or gravel) incrementally to full load. A convenient increment is 10% of load.

Deadweight method

Suitable for high accuracy weigh systems, but limited to vessels of about 12,000 lbs due to difficulty in obtaining and working with weights larger than 3,000 lbs.

Acceptable to Weights & Measures agencies.

Requires some means of attaching certified weights to weigh vessel without damage to vessel or attachments, without tipping the vessel, and with adequate working room. (Refer to section on Vessel Design for lifting lug suggestions.)

Certified weights should be ordered from a local scale company in increments of at least 5% of live load, preferably 10%.

Calibrate weigh system electronically, adjusting zero and span to keep final adjustment with weights to a minimum.

Procedure:

1. With vessel in final configuration, including all piping, stay rods, weight lifting equipment such as chain falls, etc, adjust instrument to read zero.
2. Attach first increment of certified weights to vessel making certain there is no mechanical interference with weights and surrounding structure.
3. Note instrument reading. It should agree very nearly with weights. If error is less than 0.03% of full scale, proceed with next step. If it is greater than 0.03% of full scale, remove weights and re-inspect vessel for mechanical restrictions.
4. Add weight increments until full scale is reached, recording reading at each step.
5. If desired, a span (calibration) correction may be made to the instrument at any load point above 25% of full scale. If a large correction is made, it may be necessary to remove weights and material from within vessel, re-zero instrument, and repeat Steps 2 through 4 so that system linearity is known.
6. After calibration sequence is complete, remove weights from vessel so it is in the same configuration as Step 1. Instrument reading should return to zero.
7. Detach all dead weight lifting gear and zero for last time.
8. In the unlikely event that noncorrectable mechanical problems cause linearity to fall outside calibration accuracy specification, some compensation may be effected inside BLH instrumentation.

Deadweight/Material Substitution method

Suitable for all high accuracy weigh systems where it is not possible to use calibrated weights to system full scale.

Acceptable to Weights & Measures agencies.

Obtain certified weights of largest capacity which can be conveniently handled. Ideally, total amount of calibrated weights should not be less than 5% of total system capacity. For example, not less than 5,000 lbs of weights should be used to calibrate a 100,000 lb system.

A suitable method must be devised to attach weights to vessel keeping in mind that the weights must be removed and re-attached several times during a typical calibration. (Refer to section on Vessel Design for lifting lug suggestions.)

Calibrate weigh system electronically, adjusting zero and span to keep final adjustment with weights to a minimum.

Procedure:

1. With vessel in final configuration, including all piping, stay rods, weight lifting equipment such as chain falls, etc, adjust instrument to read zero.

system calibration

Deadweight/Material Substitution method (continued)

2. Attach certified weights to vessel making certain there is no mechanical interference with weights and surrounding structure.
3. Note instrument reading. It should agree very nearly with weights. If error is less than 0.03% of full scale, proceed with next step. If it is greater than 0.03% of full scale, remove weights and re-inspect the vessel for mechanical restrictions.
4. With weights removed add weight into vessel with whatever compatible material is available (usually water or product) until exact same reading is obtained as with calibrated weights in Step 3.
5. Again attach weights, record reading and remove weights.
6. Add weight into vessel to obtain same reading as in Step 5.
7. Repeat this deadweight/material substitution procedure until desired full scale of weigh system is reached.
8. If desired, a span (calibration) correction may be made to the instrument at any load point above 25% of full scale. If a large correction is made, it may be necessary to remove weights and material from within vessel, re-zero instrument, and repeat Steps 2 through 7 so that system linearity is known.
9. After the calibration sequence is complete, remove weights and all material inside vessel so it is in same configuration as Step 1. Instrument reading should return to zero.
10. Detach all dead weight lifting gear and zero for last time.
11. In the unlikely event that noncorrectable mechanical problems cause linearity to fall outside calibration accuracy specification, some compensation may be effected inside the BLH instrumentation.

Influence of vessel piping and support deflection

Introduction

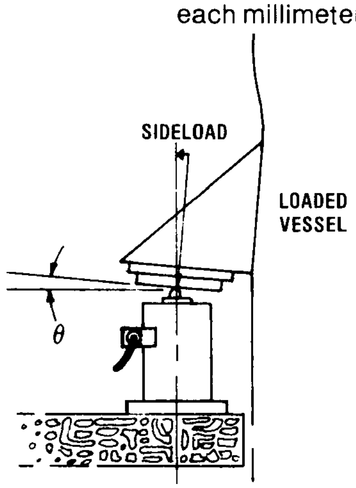
Weigh system problems sometimes arise after a system has been put into operation. The principal cause of these problems are mechanical restrictions to, and interaction with, the weigh vessel. The cause is invariably excessive vessel or support deflections which may have been identified, but assumed to be insignificant, during the design phase, or were so obscure that they went undetected. In an effort to ensure that BLH Electronics weigh systems function properly in all situations and environments, we now present some of the common and uncommon deflection problems that have come to our attention. (The problems are arranged, not by incidence or severity, but simply from the vessel up).

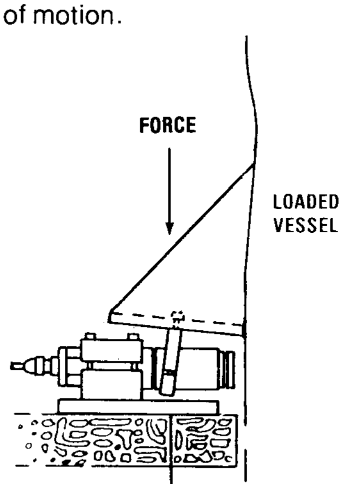
Vessel support bracket

Problem - As live load increases, so does the deflection of the vessel wall under the support bracket, causing the bracket to tilt. This generates "sideloading" of the load cell by horizontal force components that are now present. Measurable readout error will result if tilt angle exceeds ½°; potentially significant error will result if the angle exceeds 1°. Further, if load cell is mounted on the bracket, a "cosine error" occurs as a function of load cell inclination from initial plumb position.

Symptom - Weigh system output is increasingly nonlinear with load.

Remedy - Use KIS beams with bearing yokes rather than canister type load cells. Should the yoke tilt as the vessel load increases, measurable error will be negligible since the actual force on the beam remains vertical. Should the yoke slide slightly, calibration will only degrade .005% for each millimeter of motion.





Vessel thermal growth

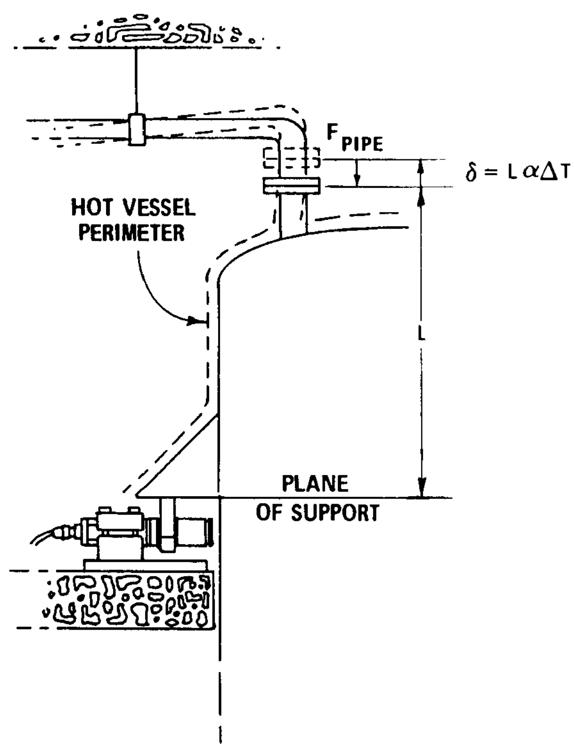
Problem - Vessel expands as it comes up to operating temperature and generates vertical piping restrictions that vary with vessel, pipe, and structure temperature. Vessel expansion is also restricted when rigid electrical conduit used for load cell cable is anchored to support structure, or when small unrelated piping is attached to the weigh vessel to carry it between floors.

Symptom - Weigh system readout registers a zero shift. If vessel operates at several temperatures, a different zero will occur for each. If weighing is performed while vessel is changing temperature, error is unavoidable.

Remedy - Specify flexible piping attachments with adequate deflection capability for vessel growth at low force levels.

- Specify flexible conduit between vessel and structure.

- NEVER ATTACH miscellaneous piping, electrical conduit, etc, to the weigh vessel for support.



special design considerations

Influence of vessel piping and support deflection (continued)

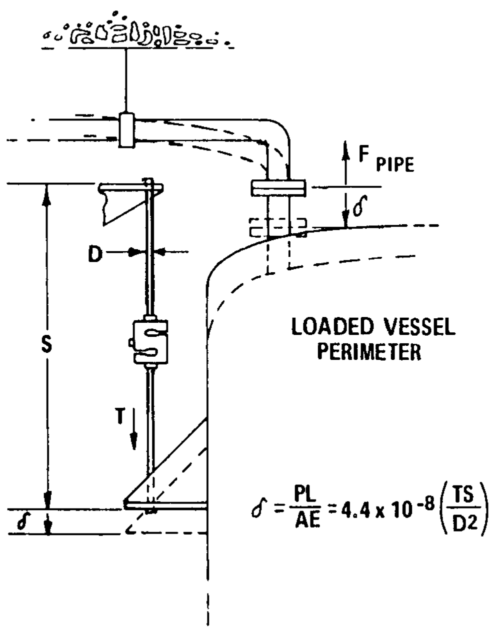
Tension linkage

Problem - Tension flexure rod linkage elongates with load. Vessel thus sinks with load, developing vertical forces in attached piping. (This is a rare problem, only arising when linkage(s) go over 100 inches in the higher capacities.)

Symptom - Weigh system output becomes increasingly nonlinear with load.

Remedy - Keep linkage elongation, δ within $\frac{1}{32}''$ under the maximum vessel live load.

- Specify flexible piping attachments.

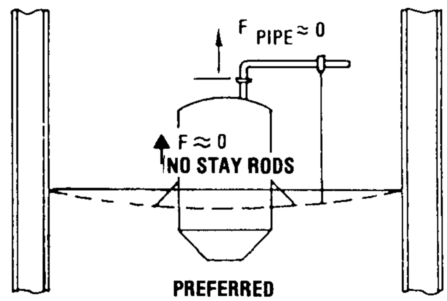


Vessel support structure

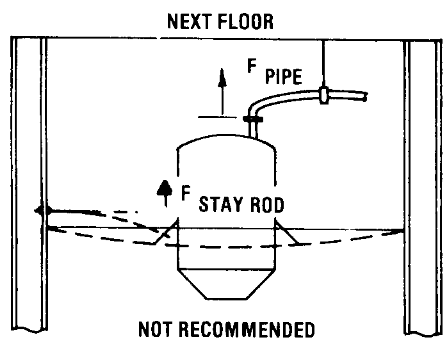
Problem - Large differential motion occurs between vessel support structure and structure support points of attached piping or stay rods. This is another common oversight made by structural and piping designers who assume the vessel to be stationary in space when in fact the support deflects with live load.

Symptom - Weigh system output may be excessively nonlinear as large vessel displacement causes mechanical restrictions to develop; e.g., attached piping and lateral restraints draw tight and generate vertical forces, or piping installed just clearing adjacent structure now contacts it at increased loads.

Remedy - Follow structural guidance provided in Structural Design section. Make piping attachments flexible. Install KIS beams rather than canister type load cells to eliminate lateral restraints. Support attached piping from structure supporting the vessel.



PREFERRED
MOUNT PIPING RESTRAINTS TO SUPPORT STRUCTURE AND USE KIS BEAMS TO ELIMINATE STAY RODS



NOT RECOMMENDED
DIFFERENTIAL MOTION GENERATES UNDESIRABLE FORCES

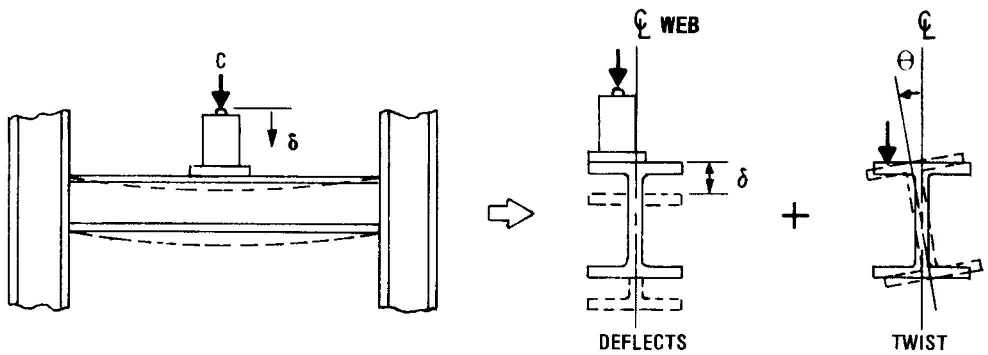
Problem - All supports, whether exposed beams or concrete floors, deflect with load. A beam, however, will also twist if load is not applied through its shear center. This problem is generally more serious for compression systems than tension systems.

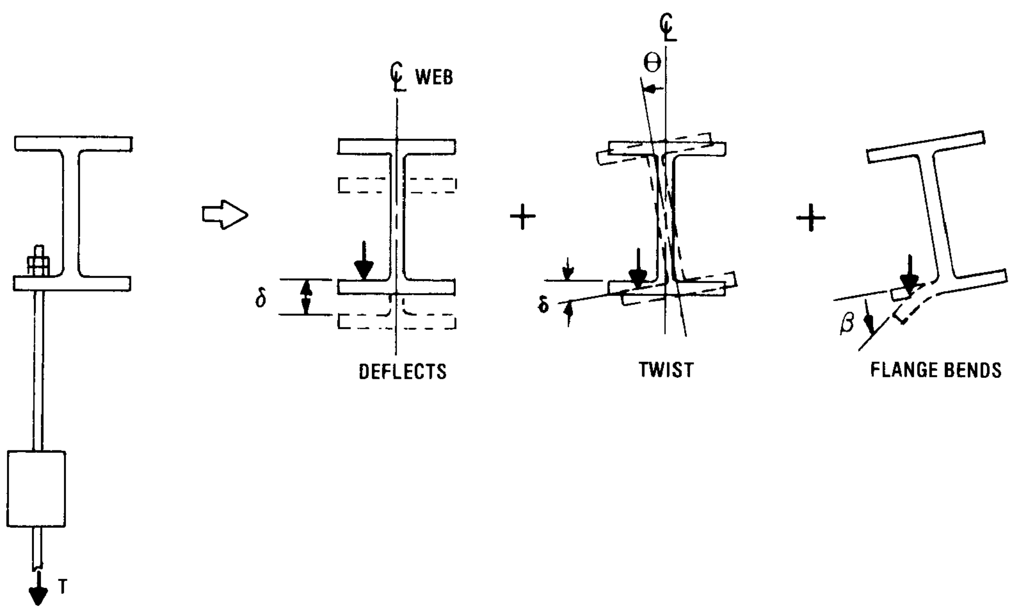
Symptom - Nonlinearities will be displayed in weigh system output as beam deflections give rise to unpredictable load cell alignments. These, in turn, incur variable cosine errors and sideload forces in compression installations and cause high bending moments in ends of tension flexure rods.

Influence of vessel piping and support deflection (continued)

Vessel support structure (continued)

Remedy - Align load transducers with shear center of support beam; preferably, only symmetric 'I' or 'WF' - beams will be used whose shear center lies on an axis of symmetry. Refer to 'Structural Design' section for additional details.





Problem - Vessel natural frequency, f, decreases with increasing structural deflection, δ, according to the formula,

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\delta}}$$

where 'g' equals the force of gravity (9.81 m/s^2 or 386 $in./s^2$).

If large support deflection occurs, the vessel may oscillate in response to nearby traffic (train, truck, forklift, crane, or just people), process equipment (pumps, agitators, diesel engines, cyclone devices, etc), internal events (fluid sloshing, chemical reactions), or wind. Structural fatigue must now be a consideration as well. Good design practice avoids natural frequencies below 4 Hz in general, 8 Hz if a compressor is in the system.

Symptom - Weigh system output oscillates, either randomly or periodically, to one or many amplitudes.

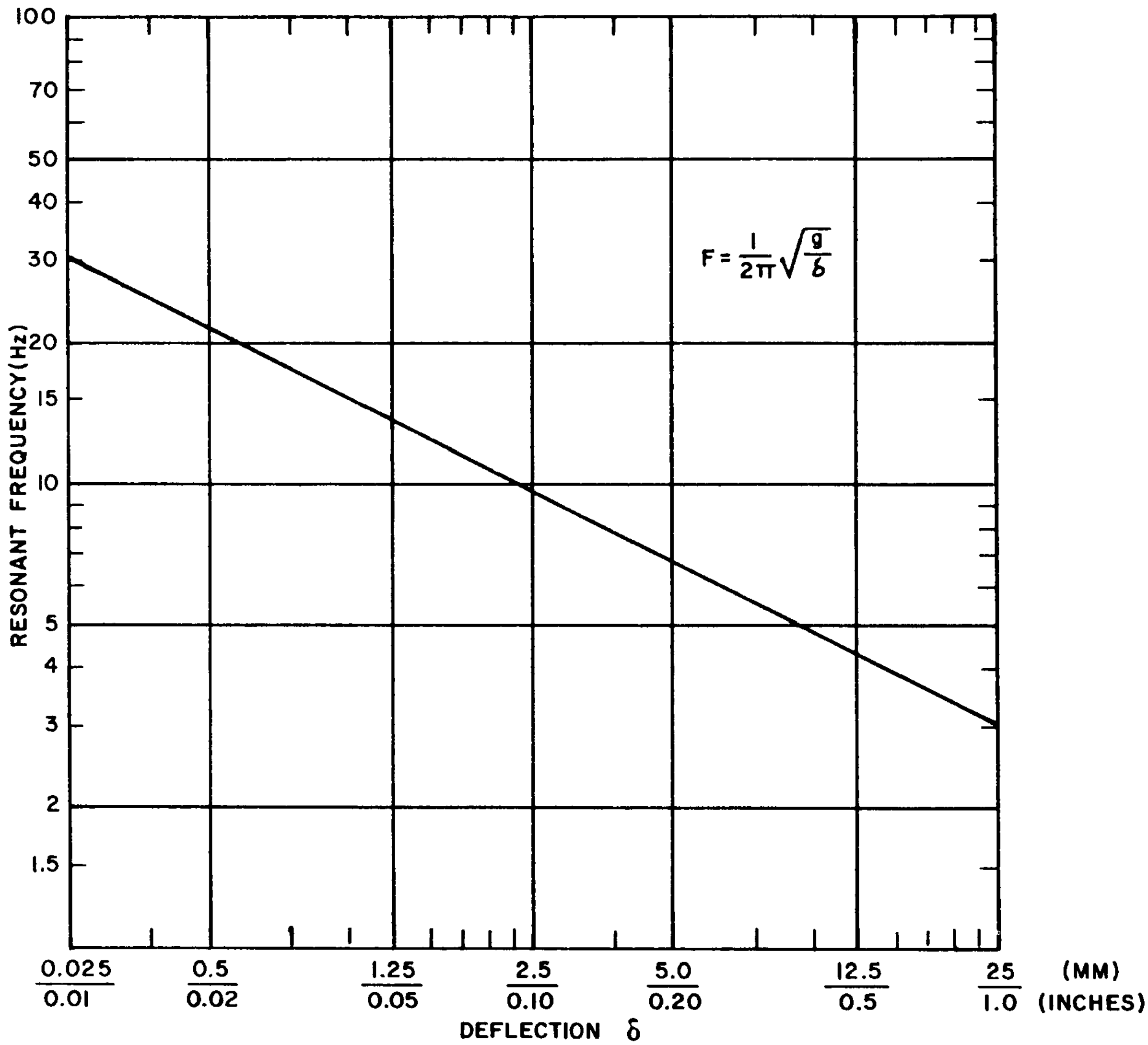
Remedy - For small oscillations, electronic filtering is available for most instrumentation. Additional filtering is possible for large oscillations by addition of large values of capacitance across load cell output.

- Stiffen support structure, curtail or isolate as much of causative activity as possible, or schedule weigh vessel operation for low activity periods.

- When high frequency forces are present, consider isolating the vibration source from the structure.

Influence of vessel piping and support deflection (continued)

Vessel support structure (continued)



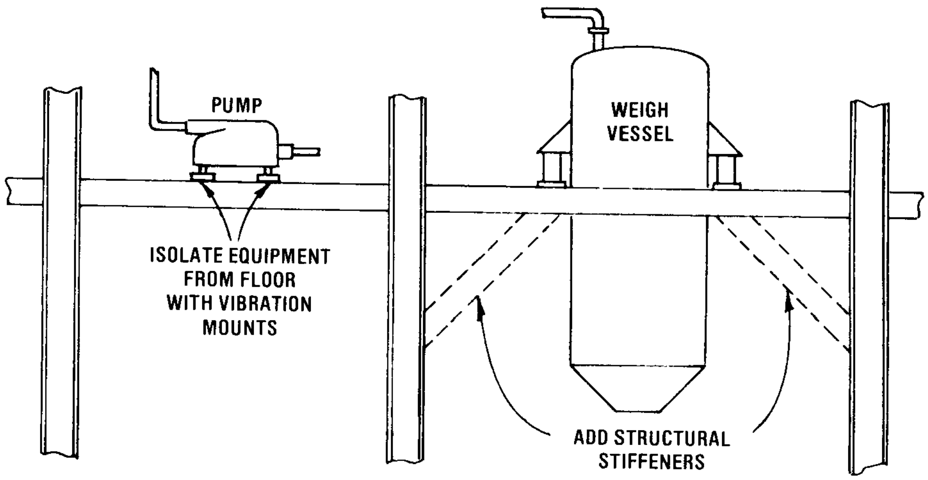
GROSS VESSEL WEIGHT SUPPORT DEFLECTION

Influence of vessel piping and support deflection (continued)

Vessel support structure (continued)

The use of vibration mounts under the weigh vessel is not recommended since this will increase deflection and lower the natural frequency.

Further, the added displacement may require reworking of external restraints and attached piping.

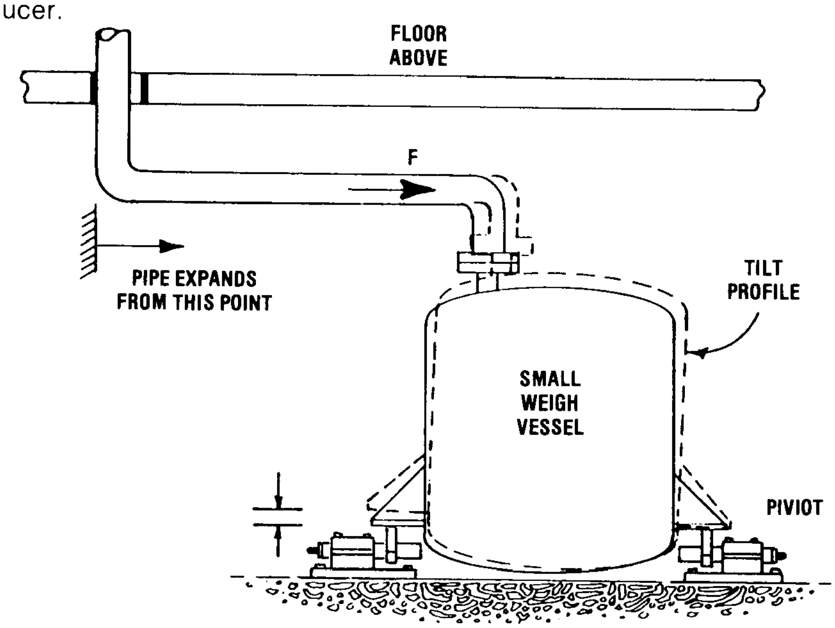


Piping thermal growth

Problem - Piping expands from fixed support to vessel attachment as hot fluid passes through. If pipe has a vertical leg between support and vessel, a vertical force may be imparted to vessel; if pipe has a major horizontal run, it may generate enough over-turning force to tilt a small weigh vessel, possibly even lifting a vessel bracket off of the load transducer.

Symptom - Weigh system zero shifts as pipe discharges hot contents then cools to ambient again.

Remedy - Attach fixed pipe support adjacent to vessel so only insignificant pipe expansion will be imposed upon weigh vessel. Specify flexible piping attachments or provide expansion loops in pipe between support and vessel.



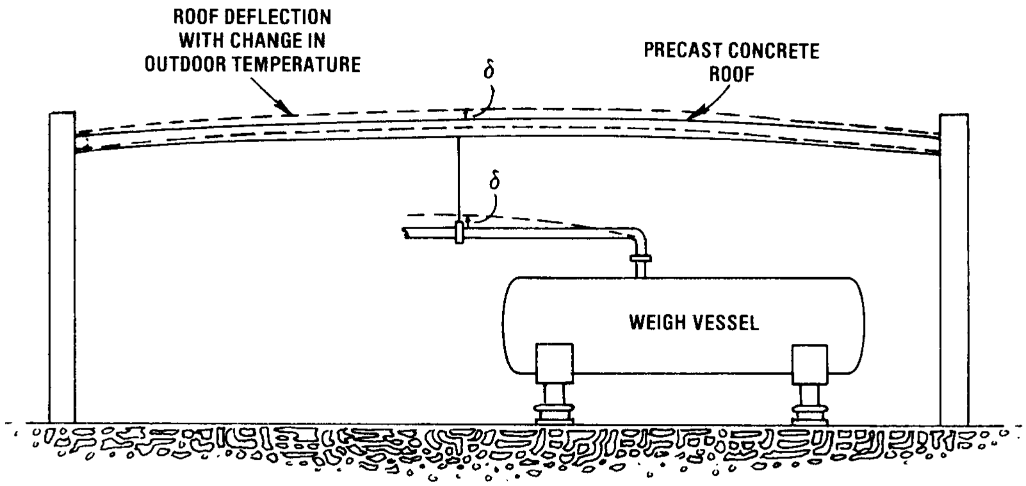
Influence of vessel piping and support deflection (continued)

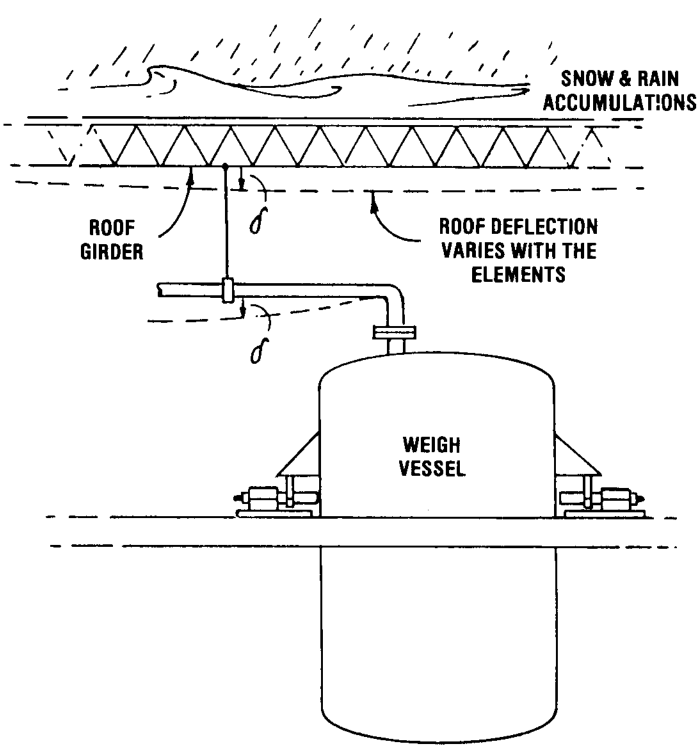
Piping support deflection

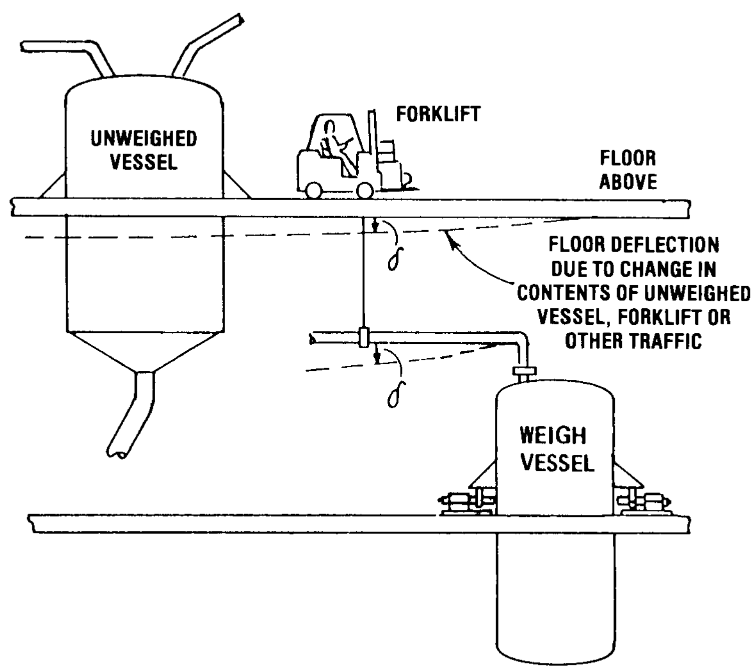
Problem - Pipe supports, especially the first supports away from vessel, deflect under random influences, generating vertical pipe forces on weigh vessel. This is, perhaps, the most common problem encountered in the field.

Symptom - Weigh system zero shifts randomly.

Remedy - Attach first pipe to same structure weigh vessel rests upon. Specify flexible pipe attachments.







Influence of vessel piping and support deflection (continued)

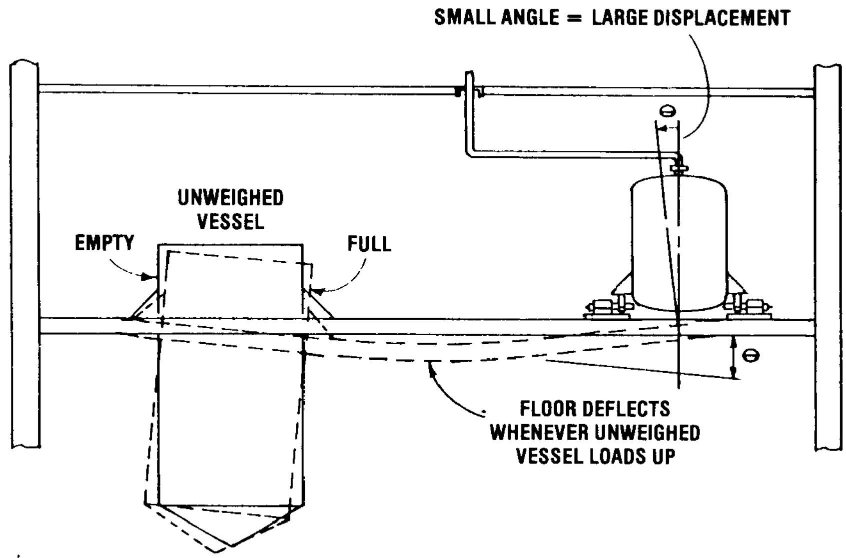
Vessel interaction

Problem - Weigh vessel support structure loses initial level and tilts as a function of another vessel on same floor. While angle of weigh vessel may be small, net displacement at point of pipe attachments may be large, introducing multiple pipe forces. Further, if weigh vessel is only partially supported on load transducers, floor tilt may upset load fraction seen by load transducers if transducer alignment is not toward other vessel.

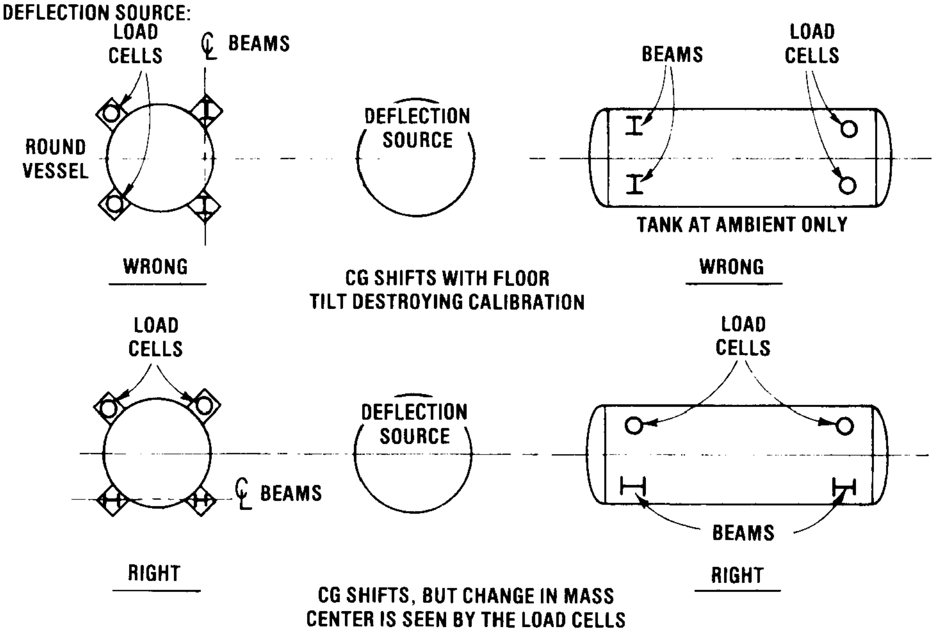
Symptom - Weigh system output inexplicably shifts even though weigh vessel contents are known to be constant.

Remedy - Specify flexible piping attachments. Support pipe from same floor weigh vessel rests upon.

- Convert partially supported weigh vessel so that it is fully supported by load transducers and floor tilt is less important. A less effective fix is to reposition the existing load transducers to line up toward the chief source of floor deflection and then observe center-of-gravity shift, at least partially.



FOR PARTIALLY - SUPPORTED VESSEL, ALIGN LOAD CELL WITH DEFLECTION SOURCE:



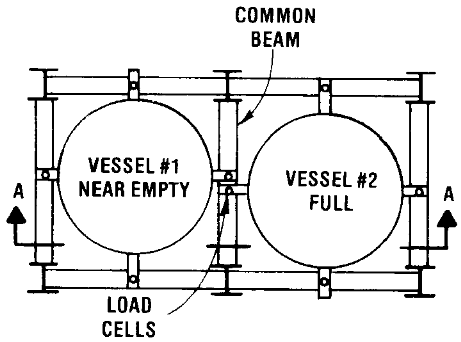
Influence of vessel piping and support deflection (continued)

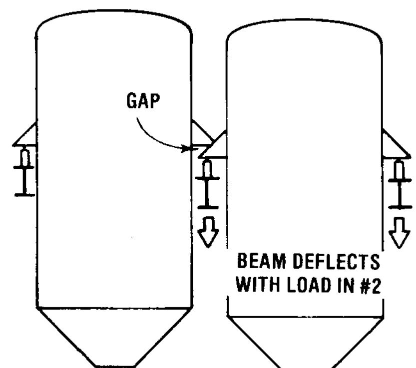
Vessel interaction (continued)

Problem - Weigh vessels aligned in a row are supported such that adjacent vessels each have a load transducer resting on a common support beam. If one vessel is then heavily loaded while adjacent vessel remains lightly loaded, lighter vessel may lose support from the now-deflected common beam. The resultant gap between load transducer and vessel bracket not only nullifies vessel calibration, but allows vessel to rock.

Symptom - Weigh system output changes and may oscillate although no change in contents has occurred as one load transducer gaps and vessel rocks.

Remedy - Use three-point supports to eliminate possibility of gapping. Do not use a common support member between two adjacent vessels. See Structural Design section for preferred vessel support arrangements.

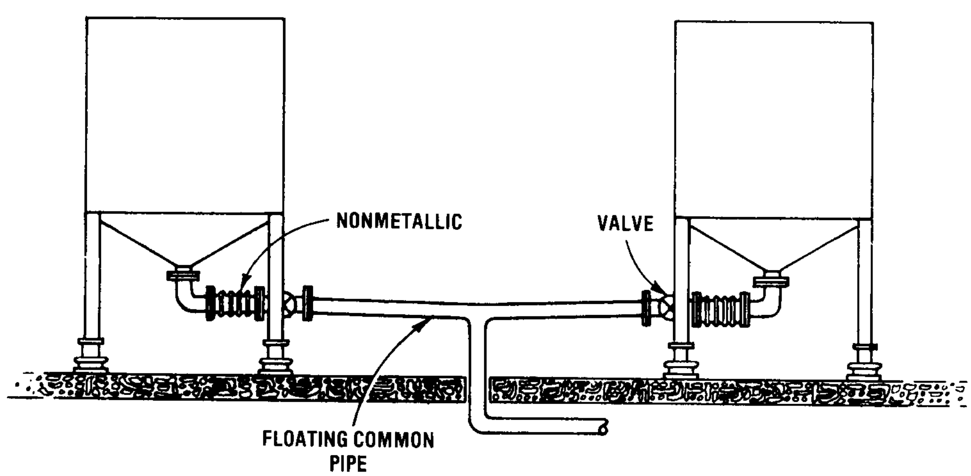




AA

Problem - Separate weigh vessels are connected to a common run of pipe. Although flexible connections are provided, the pipe is still partially supported by both vessels. Thus, in the example shown, a drain operation from one vessel causes an apparent weight increase in the other vessel for the duration of the operation.

Symptom - Output of one vessel shifts with operations at connected vessel.

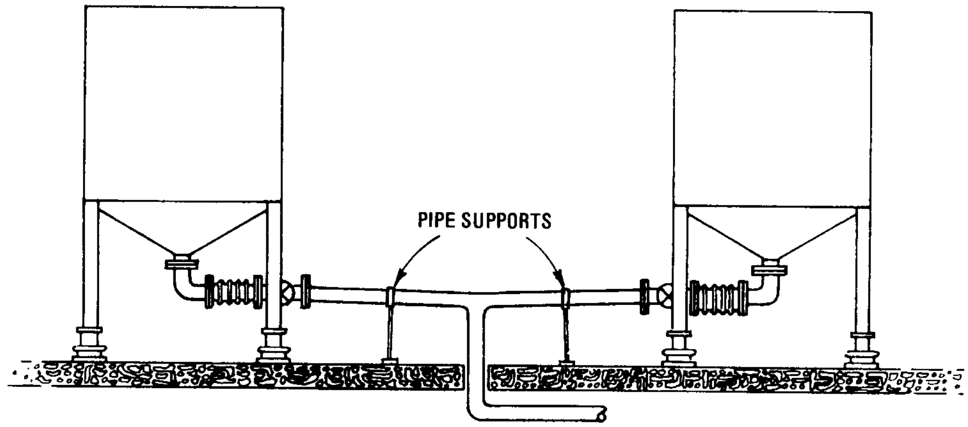


NOT RECOMMENDED

Influence of vessel piping and support deflection (continued)

Vessel interaction (continued)

Remedy - Isolate common piping with supports independent of both vessels.



PREFERRED

Outdoor installations

- Rigid vessel support foundations are essential. Foundations that heave, sink, or otherwise shift with time alter the initial level of the vessel and thus, the support reactions seen by the load transducers.
- Consider a shelter for the vessel when system accuracy better than ¼ % is required and when high wind, snow, or ice conditions are prevalent. Snow and ice alter the vessel tare weight while wind forces may impose positive or negative lift on the vessel; all unpredictably.
- Piping expansion loops or flexible piping connections are essential to accommodate differential thermal expansion between vessel, piping, and piping support structure, and to allow unrestricted deflection of load transducers.
- Platforms and ladders attached to a weigh vessel should be totally supported either by surrounding structure or foundation, or by weigh vessel alone. Contact with any other vessel, structure, or foundation can couple the weigh vessel to it, causing unpredictable readout errors.
- A free-standing blind of sheet metal or a wrap of thermal insulation is advisable for load transducers directly subjected to radiant heat or wind chill. The nonuniform thermal gradients produced in the load transducer by these environmental effects cause temporary zero shifts in load transducer outputs.

Arc welding on a weigh vessel

- THE DAMAGE MECHANISM IS HEAT. Welding can damage a load transducer only if welding current passes through the transducer; induced voltage will not harm the load transducer. When several hundred amps pass through the steel element of a load transducer, resistance (I^2R) heating occurs. Should the element temperature exceed several hundred degrees Fahrenheit, the adhesive that bonds the strain gages to the element will begin to decompose. In short, welding across a load transducer will very likely cause irreparable damage to the unit.
- ARC WELDING PRECAUTIONS:

  Before load transducer installation...

  Perform as much vessel fabrication as possible prior to load transducer installation. Use simulated load cells or dummy beams during vessel construction. See Accessory sections for installation detail.

  After load transducer installation...

  Attach the welder ground lead directly to vessel, preferably adjacent to weld site. When this is

Arc welding on a weigh vessel (continued)

not possible, put high-current-capacity cables across each load transducer to ground vessel to structure. DO NOT rely on stay rods or piping for grounding; rods generally have high resistance terminations, while the piping may contain non-conductive flexible couplings.

Where routine welding maintenance is anticipated, permanent ground cables are advised. Braided-copper automotive ground straps are suitable for this purpose.

Technical data for calculating rod lengths

Request BLH Document - TECHNICAL DATA/Tension Flexure Rods (TD 063)

Sizing of lateral restraints

Request BLH Document - TECHNICAL DATA/Sizing of Lateral Restraints (TD 068)

Piping flexibility

Introduction

A weigh vessel, without any mechanical attachments, fully supported by load transducers mounted on a firm base will demonstrate a system accuracy approaching that of load transducer and instrumentation alone, a value well below 0.1%. If lateral restraints are now added in the form of stay rods attached to nearby floor brackets, system accuracy should remain undisturbed, provided that installation rules are observed. A similar statement can be made for vented weigh vessels since inlet and outlet piping need not contact vessel; simply pass inlet piping through an oversize clearance hole in the top of the vessel (when there is an upper surface) and let outlet piping lead into a funnel arrangement underneath. Details are presented in the section titled 'Piping Design.'

When problems do arise, they generally involve sealed systems requiring piping to be attached directly to vessel. Here piping is an active part of the weigh system; any motion of the vessel relative to piping and vice versa will generate vertical and horizontal reaction forces on the weigh vessel. Rules governing the magnitudes of these forces are the subject of this section.

Design criteria

The total vertical force, V, generated by the deflection of all piping attached to a weigh vessel should not exceed a percentage of the maximum live load, L, proportional to the required weigh system accuracy, A...

$$V \leq (10A)L$$

where: A = system accuracy, in percent

Hence, for a 0.1% system, V $\leq$ 1.0%L;
for a 0.25% system, V $\leq$ 2.5%L;
for a 0.5% system, V $\leq$ 5.0%L;
for a 1.0% system, V $\leq$ 10.0%L.

This total vertical piping force represents the sum of individual vertical piping reactions, Pi, generated by differential motion between pipe anchorages (i.e., the point of attachment on vessel and first pipe support) and by thermal expansion in vertical segments of pipe located between anchorages. These forces often can and should be minimized by mounting first pipe support to vessel support structure and using only horizontal piping runs between vessel and first pipe support.

The force criterion is intended to maintain highly linear piping response suitable for the most accurate weigh systems, yet permit increasing amounts of nonlinear forces to develop without impairing the required weigh system accuracy. It follows that more care and expense is required for the design and installation of piping on a high accuracy vessel than for a low accuracy vessel.

The total vertical deflection, δv, to be evaluated for each run of pipe attached to a weigh vessel is equal to the algebraic sum of all imposed deflections...

$$\delta v = \delta s + \delta tv + \delta tp + \delta a$$

where: δs = vessel support deflection

δtv = vessel thermal expansion to point of pipe attachment (e.g., nozzle or flange)

δtp = pipe thermal expansion in vertical runs of pipe

δa = deflection of first pipe support or anchorage, a value often independent of vessel support structure

Deflections tending to increase indicated vessel weight are given positive signs, and vice versa.

When several combinations of deflections are possible, determine which is the limiting condition and base the piping design on it. For example, a weigh vessel on one floor may be directly attached to a storage vessel on floor above as illustrated in Figure 1. Assume there is no other attached piping present. If weigh vessel is fully loaded when storage vessel is empty, $\delta a \approx 0$, but, δs (and thus δv) may be -0.5 inch (12.7 mm). At some later time, the storage vessel may be filled causing an anchor motion of, say 0.25 inch, so that $\delta a = +0.25$ inch (6.35 mm) and $\delta v = -0.25$ inch. For this simplistic example, the limiting case is when the weigh vessel alone is fully loaded.

The minimum vertical deflection, δv, to be applied to any pipe is -0.100 inch (-2.54 mm). Use this value whenever more significant deflections cannot be identified; it is intended to cover the dimensional change of load transducer under live load — generally under 0.010 inch (.254 mm), as well as a modest amount of cold-springing required for initial pipe alignment.

Piping flexibility (continued)

Design criteria (continued)

A more common situation is that of a weigh vessel supported from a building floor or steel framework. Such vessel support structures generally exhibit maximum vertical deflections of 0.25 inch (6.35 mm) to 0.50 inch (12.7 mm) under gross vessel weight, although some installations have deflections approaching 0.75 inch (19.05 mm). If a realistic evaluation can be performed for the maximum vessel support deflection, let δs be the resulting value. Otherwise, take $\delta s = 0.50$ inch as a reasonable estimate.

Vessel thermal expansion, δtv, is determined from the expression:

$$\delta tv = L \alpha \Delta T$$

where: L = distance between vessel plane of support and pipe attachment point

α = coefficient of thermal expansion, with max. values of $9.6 \times 10^{-6}/°F$ ($1.7 \times 10^{-5}/°C$) for stainless steel and $8.4 \times 10^{-6}/°F$ ($1.5 \times 10^{-5}/°C$) for carbon steel.

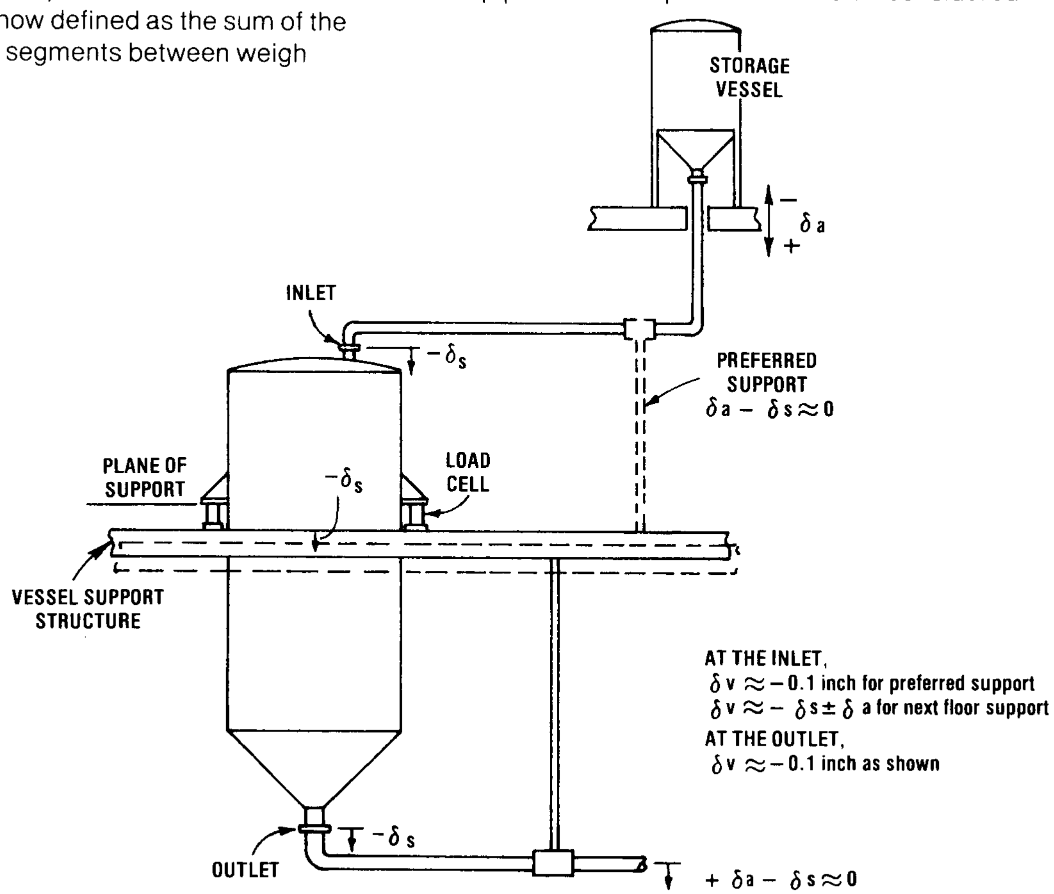
ΔT = maximum vessel operating temperature minus ambient temperature.

Pipe thermal expansion, δtp, is evaluated as indicated above except that L is now defined as the sum of the lengths of vertical pipe segments between weigh vessel and first pipe support. This parameter may be ignored when pipe expansion is below 0.050 inch (1.27 mm).

Pipe anchor deflection, δa, is a significant factor in weigh system performance. Refer to the sources of floor deflections in section entitled, "Special Design Considerations" before assigning a value.

NOTE: It remains the responsibility of the vessel or pipe designer to ensure that the level of stresses in piping, vessel attachments, and pipe supports is in accordance with applicable piping and vessel design codes. It is also incumbent upon the designer to ensure that forces and moments imposed on associated process equipment by vessel piping are within limits specified by equipment manufacturer.

DISCUSSION OF DESIGN CRITERIA - In applying the vertical force rule, the piping designer must assign realistic values of deflection to each piping run attached to the vessel. This means that vessel support deflection, vessel thermal expansion, pipe support deflection, and pipe thermal expansion should be considered.



Piping flexibility (continued)

Design criteria (continued)

DISCUSSION OF DESIGN CRITERIA (continued)

For example, the vessel at constant ambient temperature shown on the previous page generates a vertical pipe reaction at the inlet as vessel support structure deflects an amount δs that varies with load; significant pipe forces are precluded at vessel outlet by attaching first pipe support to vessel support structure, thereby minimizing differential motion between pipe and vessel.

For this case, it is obviously beneficial to support all piping from vessel support structure so that attached piping moves only with vessel, isolating weigh system from motion of other floors and equipment. Whatever forces do develop are primarily due to installation fitup and are essentially constant, contributing only to vessel tare weight.

Design the piping runs from vessel to first supports with sufficient flexibility to meet vertical force criterion consistent with system accuracy required.

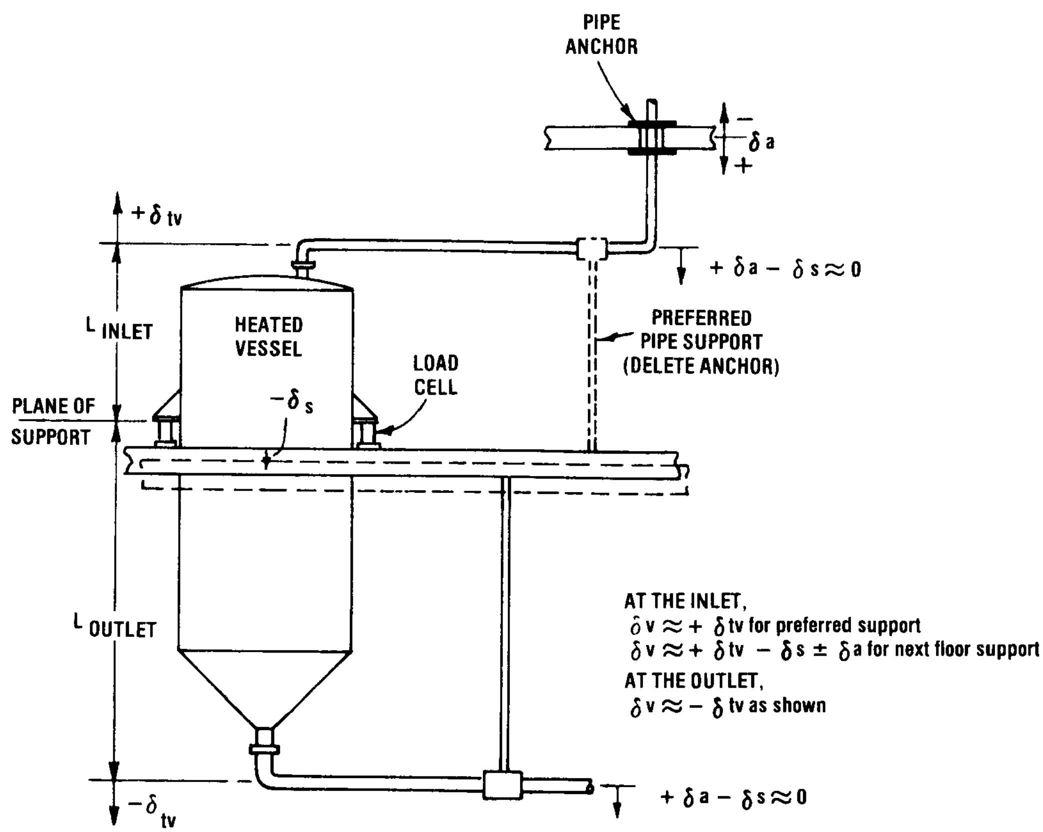
Let the vessel now operate at some constant temperature above ambient. As indicated below, vessel thermal growth affects both inlet and outlet piping. Estimate vessel expansion at each end of vessel from

$$\delta tv = L \alpha \Delta T$$

as previously discussed. Vertical displacements at both inlet and outlet are the algebraic sum of:

$$\delta v = \delta tv + \delta s + \delta a$$

It is again beneficial to support all piping from the vessel support structure to achieve weigh system isolation. In fact, the only difference between this case and the first is the need for additional flexibility of each piping run to assure a linear response to vessel deflection with load in spite of imposed thermal expansion.

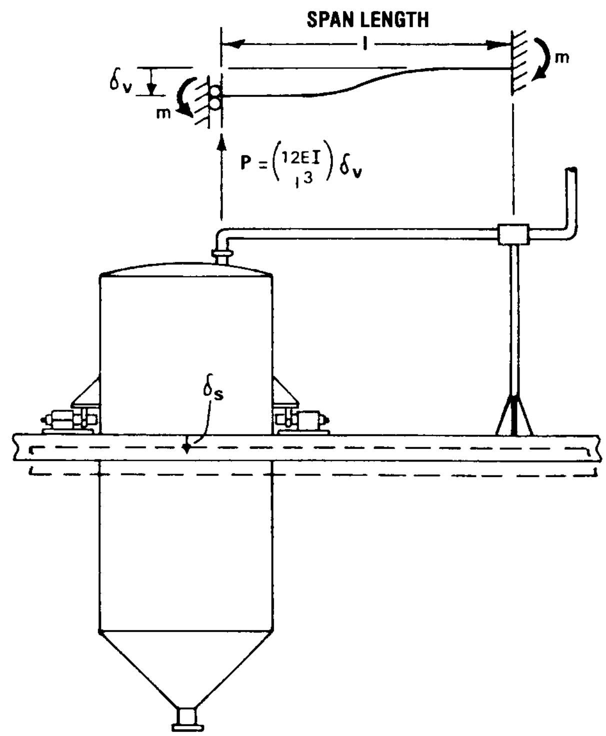


Piping flexibility (continued)

Design criteria (continued)

DISCUSSION OF LATERAL PIPING FORCES - Lateral piping forces are seldom significant for weigh vessels fully supported on load transducers: the requirement for vertical flexibility automatically imparts a degree of lateral flexibility to attached piping; the lateral force resultant is reacted by the lateral restraints; and the net overturning moment, while partially unloading a load transducer(s) on one side of the vessel, merely adds load onto load transducer(s) on the other side without a change in indicated vessel weight. Rarely is the overturning moment large enough to actually lift the vessel and cause gapping to occur between load transducer and vessel.

Lateral piping forces are more likely to cause problems for weigh vessels partially supported on load transducers since any overturning moment that arises is likely to alter the weigh system output. Refer to the 'Piping Design' section for suggestions on minimizing piping influence.



Design analysis for piping

INTRODUCTORY COMMENTS - The information presented herein will enable the reader to estimate the total vertical piping force acting on a vessel. If this resultant force exceeds live load criterion, action should be taken to introduce additional flexibility into the piping system. This may be accomplished, for example, by increasing the horizontal length of piping between vessel and first pipe support, redesigning attached piping to include a right angle segment or expansion loop, inserting a flexible device, or specifying a lighter schedule pipe. Refer to "Piping Design" section for suggestions.

Specific designs for piping cannot be pre-engineered for limiting cases and presented in design charts, as for stay rods. There are few, if any, "standard" piping configurations. Identical vessels installed in different buildings will still require customized piping runs to accommodate changes in floor height and stiffness or associated equipment. Hence, the piping design analysis is necessarily left in basic form.

Two figures presented in this section show pipe spring rate as a function of span length for Schedule 40 pipe and, a more general chart, spring rate as a function of span length and pipe moment-of-inertia. These figures yield conservative, high-side values for spring rate that may be modified by factors derived below.

PIPING FLEXIBILITY OVERVIEW - The vertical reaction force, Pi, developed in one straight span of pipe in response to differential vertical motion, δvi, between fixed end points is: $Pi = Ki\ \delta vi$

where: Ki = spring rate, or pipe stiffness

For all piping attached to a weigh vessel, the summation of individual pipe reactions, Pi, should meet the vertical force criterion...

$$V = \left|\Sigma Pi\right| = \left|\Sigma Ki\ \delta vi\right| \leq (10A)L$$

where: A = system required accuracy, in percent

L = maximum live load.

The points discussed hereafter are intended to aid in estimation of overall vertical piping forces acting on a weigh vessel as piping layout is being generated. More accurate force values, when warranted, may be obtained by using computer programs specifically written for piping analyses.

SPRING RATE, K - As indicated above, the stiffness of a pipe fixed at one end against all deflection and rotation, and guided at the other is given as:

$$K = \frac{12EI}{l^3}$$

This value represents an upper bound that is not achievable because of inherent flexibility of vessel nozzles, flanges, or wall itself, and of the pipe support. The piping industry recognizes this and generally uses:

$$K = \frac{10EI}{l^3}$$

for average runs, a compromise between a beam with fixed ends (above) and $K = \frac{8EI}{l^3}$ for a beam simply supported at both ends*.

*M. W. Kellogg Company, Design Of Piping Systems, 2nd Edition, John Wiley & Sons, pg. 239.

Piping flexibility (continued)

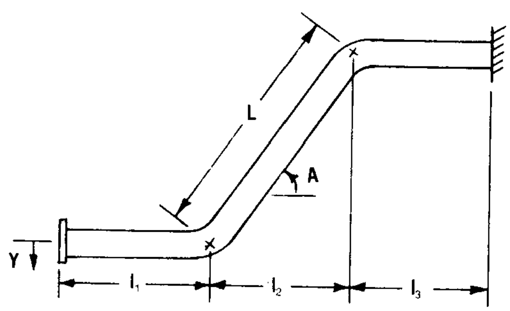
Design analysis for piping (continued)

SPRING RATE, K (continued)

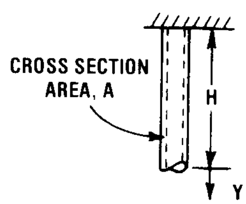
The spring rate developed in the charts on the next two pages are based upon the theoretical fixed end condition with an additional design factor of two applied. For this analysis, these spring rates should be derated by a ratio of $\left(\frac{10}{24}\right)$ or 0.42.

Thus, the corrected vertical force equation should read, $P = 0.42K\ \delta v$, where K is read directly from the Figures.

NOTE: Effective length for a nonhorizontal pipe span is equal to its projected length on the horizontal plane; $l = L \cos A$. A vertical run of pipe has zero span length, and may be considered to have infinite stiffness for the purposes of this analysis.



$l = l_1 \quad l_2 \quad l_3, K = \frac{10EI}{l^3}$



$K_{AXIAL} \gg$ TYPICAL $K_{LATERAL}$

$$\frac{AE}{H} \gg \frac{10EI}{l^3}$$

FLEXIBILITY TRENDS - To increase the flexibility of a straight run of pipe, add a horizontal leg at right angles. The straight run now benefits from both bending and torsional deflection of the leg.

For example, consider a pipe span, cantilevered from a "rigid" anchor, with an enforced deflection, y at the free end. The vertical reaction, W_O is:

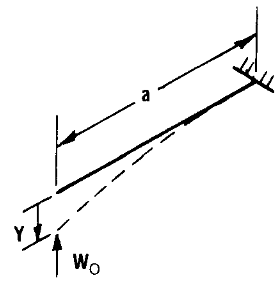
$$W_O = \left(\frac{3EI}{a^3}\right) y$$

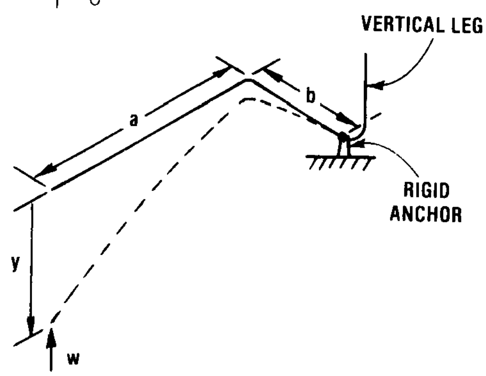
If a right angle leg of length b is now added, the reaction becomes:

$W \approx \left(\frac{1.68EI}{a^3}\right) y$, or 56% W_O when b = .2a

$W \approx \left(\frac{EI}{a^3}\right) y$, or 33% W_O when b = .5a

$W \approx \left(\frac{EI}{2a^3}\right) y$, or 17% W_O when b = a





FINAL VERTICAL FORCE EQUATIONS - Assuming these trends to hold for the fixed-guided condition and rounding up for a modest element of conservatism, the pipe reaction force, P, becomes:

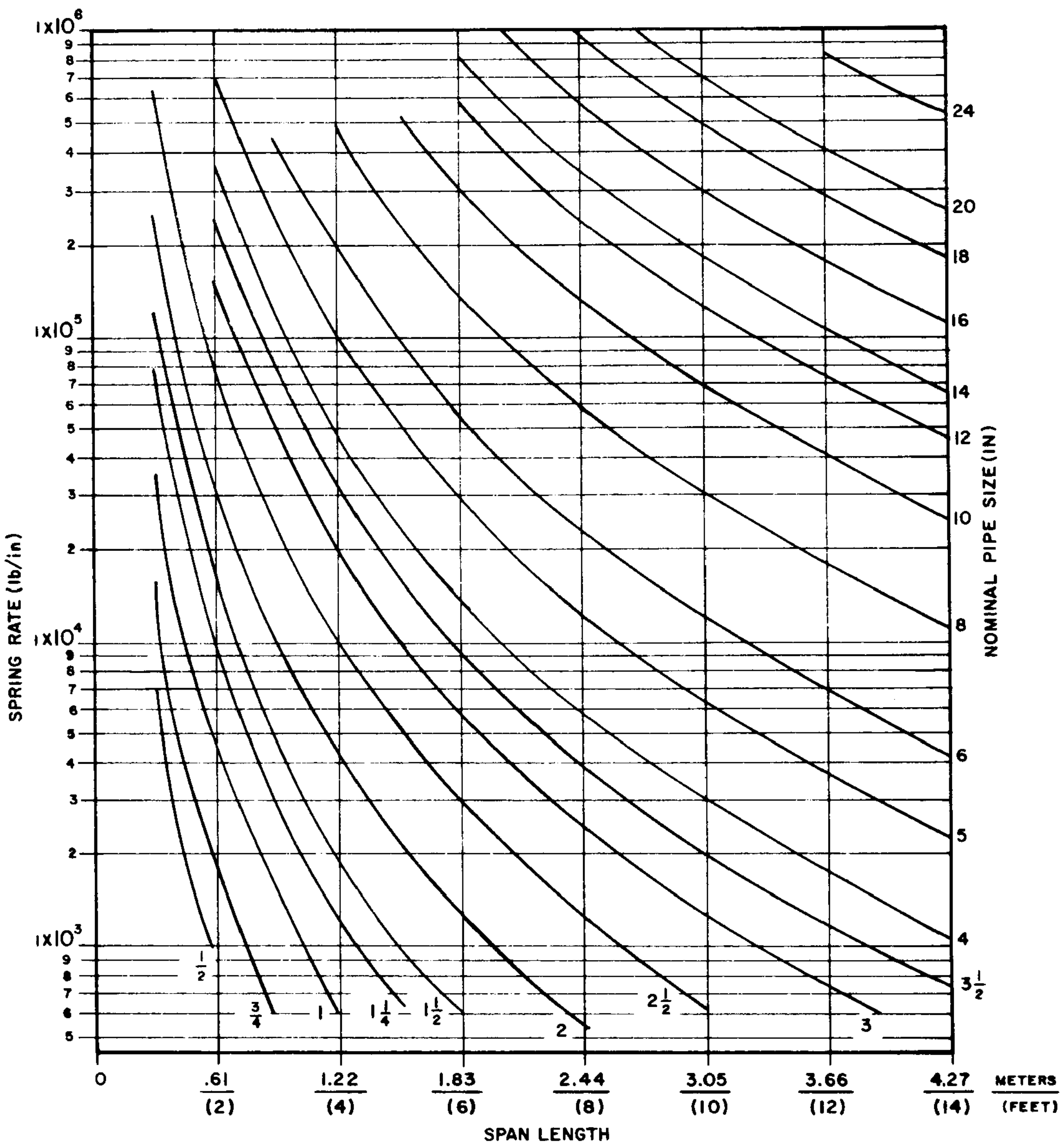
$P \approx 0.5K\ \delta v$ for a straight run of pipe
$P \approx 0.3K\ \delta v$ for a right angle bend with b = .2a
$P \approx 0.2K\ \delta v$ for a right angle bend with b = .5a
$P \approx 0.1K\ \delta v$ for a right angle bend with b = a

where K is read directly from Figures 4 and 5. It should be understood that these equations are not exact, but are adequate for estimating the vertical piping forces for comparison with the empirical design criterion.

special design considerations

Piping flexibility (continued)

Design analysis for piping (continued)

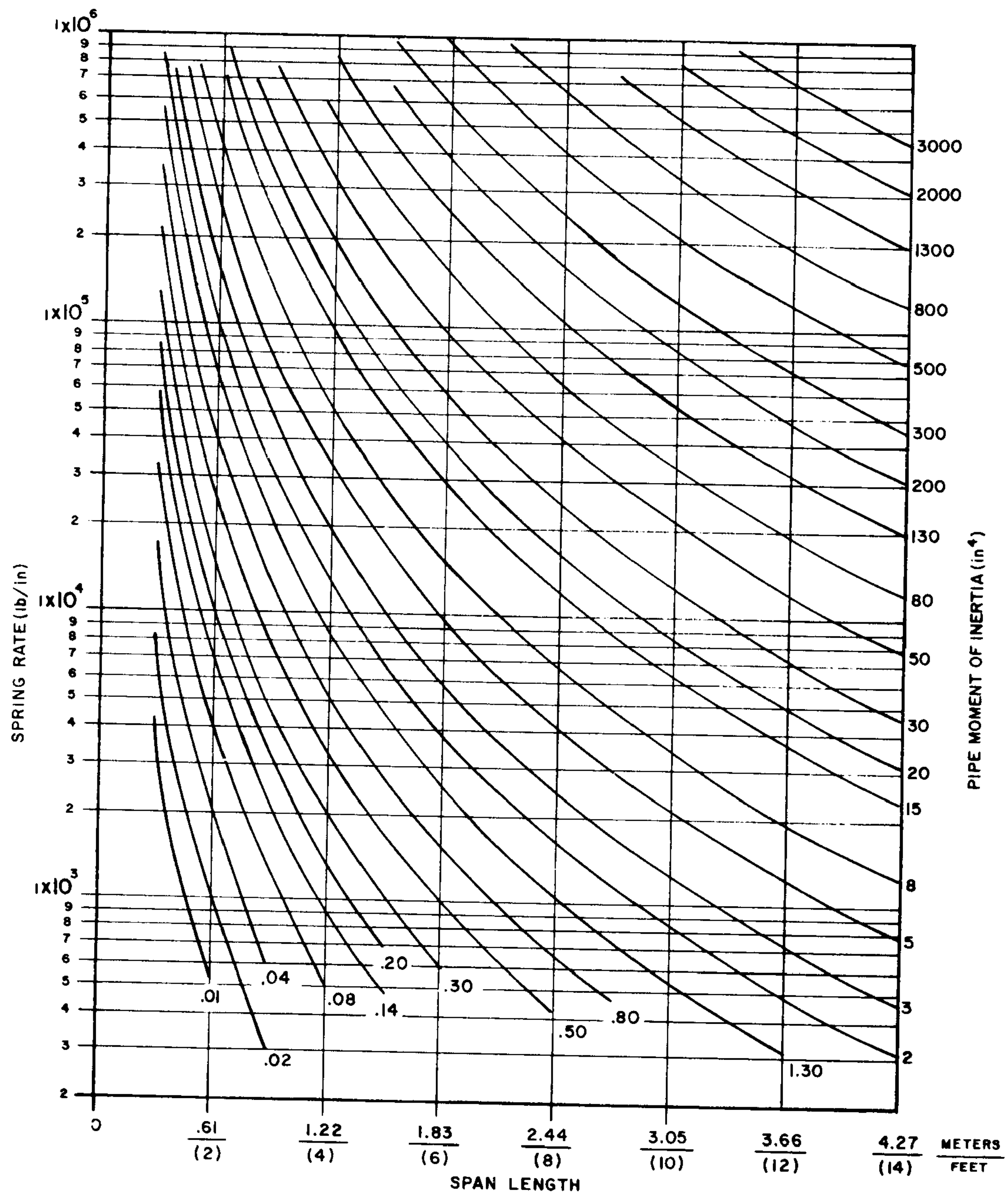


SPRING RATES FOR SCHEDULE 40 STEEL PIPE

NOTE: Spring rate obtained from the above chart should be derated by 0.42.
(Refer to section on Spring Rate)

Piping flexibility (continued)

Design analysis for piping (continued)



SPRING RATES FOR STEEL PIPE

NOTE: Spring rate obtained from the above chart should be derated by 0.42. (Refer to section on Spring Rate)

Piping flexibility (continued)

Stiffness of flexible piping devices

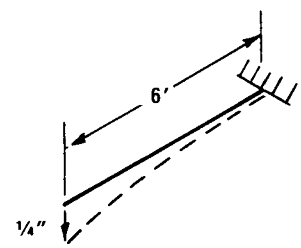
A misconception regarding flexible devices such as expansion joints and flexible couplings is that, once installed, they accommodate all motions imposed upon them without significant force reactions. That this is generally untrue is shown in Table 1, where several different piping layouts are compared, leading to the following observations:

(1) The use of horizontally-positioned universal joints is recommended whenever spacial requirements preclude the use of much longer offset piping runs. It is incumbent upon the piping designer to request applicable stiffness data from the manufacturer of the flexible fitting prior to finalizing his piping layout.

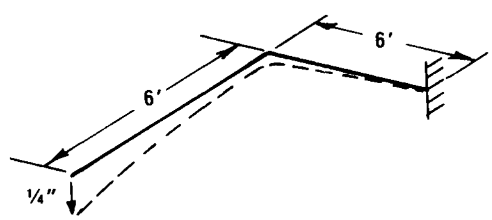
(2) Lighter schedule stainless steel piping (e.g., schedules 10S and 5S) offer significant improvements in flexibility over the standard heavier schedule carbon steel piping commonly used.

Vertical reaction forces generated by a 0.25 inch (6.35 mm) end deflection

NOMINAL PIPE SIZE (mm/in.)	STEEL PIPE Sch 40 (kg/lb)	STEEL PIPE Sch 10S (kg/lb)
76.20 / 3.00	325 / 715	204 / 450
304.80 / 12.00	34,050 / 75,000	14,755 / 32,500

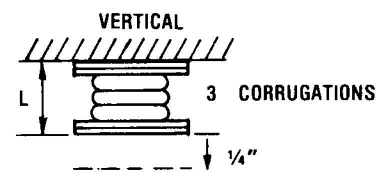


NOMINAL PIPE SIZE (mm/in.)	STEEL PIPE Sch 40 (kg/lb)	STEEL PIPE Sch 10S (kg/lb)
76.20 / 3.00	66 / 145	41 / 90
304.80 / 12.00	6810 / 15,000	2950 / 6500



EXPANSION JOINT[1] - VERTICAL

MINIMUM L (mm/in.)	STEEL (kg/lb)	MINIMUM L (mm/in.)	TEFLON (kg/lb)
238 / 9.375	123 / 270	92.10 / 3.625	27.20 / 60
356 / 14.00	141 / 310	200 / 7.875	43.10 / 95



EXPANSION JOINT[1] - HORIZONTAL

MINIMUM L (mm/in.)	STEEL (kg/lb)	MINIMUM L (mm/in.)	TEFLON (kg/lb)
238 / 9.375	329 / 725	92.10 / 3.625	47.70 / 105
356 / 14.00	1105 / 2435	200 / 7.875	114 / 250

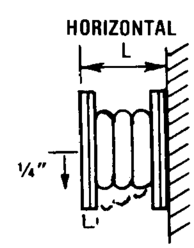


TABLE 1

Piping flexibility (continued)

Vertical reaction forces generated by a 0.25 inch (6.35 mm) end deflection (continued)

UNIVERSAL JOINT[2]

MINIMUM M (mm/in.)	STEEL (kg/lb)	TEFLON (kg/lb)
689 / 27.13	2.72 / 6	1.82 / 4
883 / 34.75	20.43 / 45	8.17 / 18

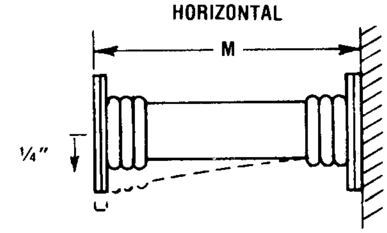


TABLE 1

NOTES:

(1) Steel expansion joint data is from Badger Expansion Joint Company, New Castle, Pa., Catalog 73B; Telfon expansion joint data is from Peabody Dore Corporation, Houston, Tx., Data Sheet BR06 and Peabody Dore Drawing A-3785B, "Table of Spring Forces". These steel joints are rated at 300 and 400 psi; the molded Teflon joints, at 150 psi.

(2) Universal joints comprise two expansion joints and an intermediate length of pipe. Teflon joints are custom items from the vendor, so data is not readily available. For comparison purposes, the same percent force reduction given for the steel joint was applied to the Teflon joint.

(3) Expansion joints and flexible couplings are made with a variety of materials, material thickness and dimensions to suit specific applications; for example, units with lower pressure ratings and greater numbers of corrugations would generate lower forces than those presented here. When inquiring of a manufacturer, stipulate the maximum stiffness required and the space available in addition to the usual information.

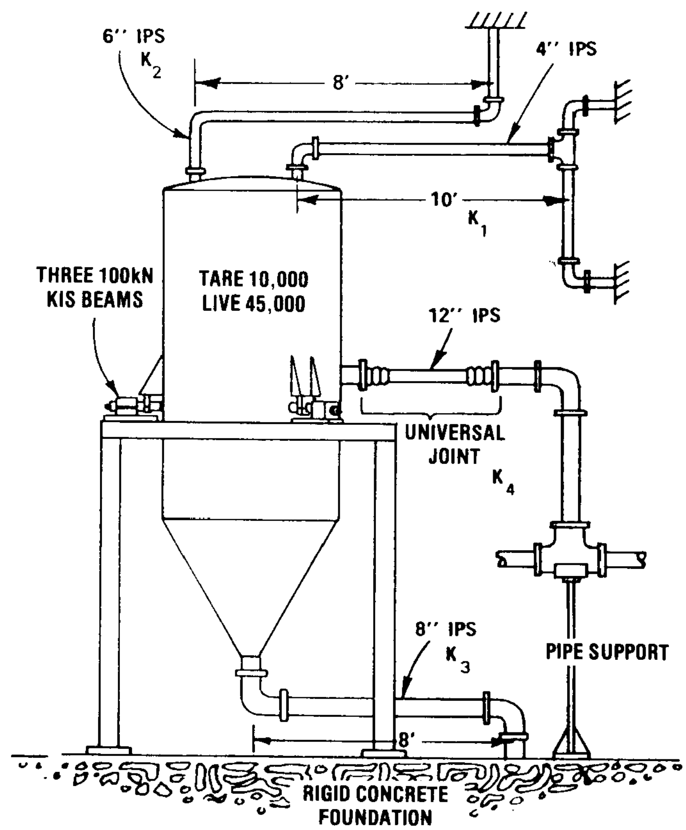
(4) A flexible device installed vertically develops vertical thrust forces with the onset of vessel pressure associated with material flow and some chemical reactions. The magnitude of these forces, V, is given by V = AP, where A is the mean internal area of the device and P is the estimated pressure. This is one reason why such devices are best installed in the horizontal runs adjacent to a high accuracy weigh vessel.

ILLUSTRATE PROBLEM...PIPING FLEXIBILITY

Given: The weigh system shown. It is an existing vessel to be retrofitted. The attached piping is schedule 40 steel except for the universal joint. An accuracy of 0.1% is required over the maximum live load, L of 45,000 lb (20430 kg). The vessel is at constant ambient temperature. All pipe anchorages are assumed to be nondeflecting. The maximum vessel support deflection is estimated to be 0.25 inch (6.35 mm).

Discussion: Since no vessel thermal expansion occurs and all pipe anchors are rigid, the vertical deflection imposed on each of the pipes is the same; that is,

$\delta V = -0.25$ inch



Piping flexibility (continued)

ILLUSTRATE PROBLEM...PIPING FLEXIBILITY (continued)

Procedure:

(1) Total vertical force – the absolute value of the total piping force permitted for this installation is:

$$V = 10AL = 10(0.1\%)L = 1.0\%L$$

$$V = 0.01(45{,}000) = 450 \text{ lb } (204 \text{ kg})$$

(2) Piping stiffness, K
Determine the appropriate pipe stiffnesses for the 4, 6, and 8-inch lines from Figure 4:

(4-inch, 10 ft. long) $K_1 = 3.0 \times 10^3$ lb/in.

(6-inch, 8 ft. long) $K_2 = 2.3 \times 10^4$ lb/in.

(8-inch, 8 ft. long) $K_3 = 5.8 \times 10^4$ lb/in.

The lateral stiffness of the 12-inch universal joint must be obtained from the manufacturer. For this problem, let $K_4 = 175$ lb/in. This assumes that the right side of the joint is to be fixed, without any allowance for the flexibility of the piping beyond that point.

(3) Vertical pipe reactions, P_i
Since each pipe has only a straight horizontal run, the applicable equation is:

$$P = 0.5K\ \delta V$$

Thus,

$$P_1 = 0.5(3 \times 10^3)(-0.25) = -375 \text{ lb}$$
$$P_2 = 0.5(2.3 \times 10^4)(-0.25) = -2875 \text{ lb}$$
$$P_3 = 0.5(5.8 \times 10^4)(-0.25) = -7250 \text{ lb}$$
$$P_4 = K_4 V = 175(-0.25) = -45 \text{ lb}$$
$$-13545 \text{ lb}$$

However, $V = |\Sigma P_i| = 13545$ lb >> 450 lb. permitted for this installation.

Discussion: Clearly 6- and 8-inch lines require redesign for a 0.1% system. Possible solutions are to:

(a) put expansion loops in both lines,
(b) change the straight spans to schedule 10S stainless, process permitting, or
(c) insert additional universal joints.

The first solution, (a), requires piping analysis beyond the scope of this manual. Solution (b) doesn't appear fruitful since the data in Table 1 suggests a decrease in pipe reaction of only 2 or 3 times, whereas a factor of at least 6 is required here. So, for this example, additional universal joints will be inserted.

(4) Universal joint stiffness
One manufacturer specifies the lateral stiffness for 3[3] corrugation metal universal joints with 300 psi ratings at:

$K_{6''} = 40$ lb/in. (overall length < 43 inch)

$K_{8''} = 70$ lb/in. (overall length < 46 inch)

(5) Vertical pipe reactions (2nd try)

$$P_1 = -375 \text{ lb}$$
$$P_2 = K_2V = 40(-0.25) = -10 \text{ lb}$$
$$P_3 = K_3V = 70(-0.25) = -20 \text{ lb}$$
$$P_4 = -45 \text{ lb}$$
$$\Sigma P_i = -450 \text{ lb}$$

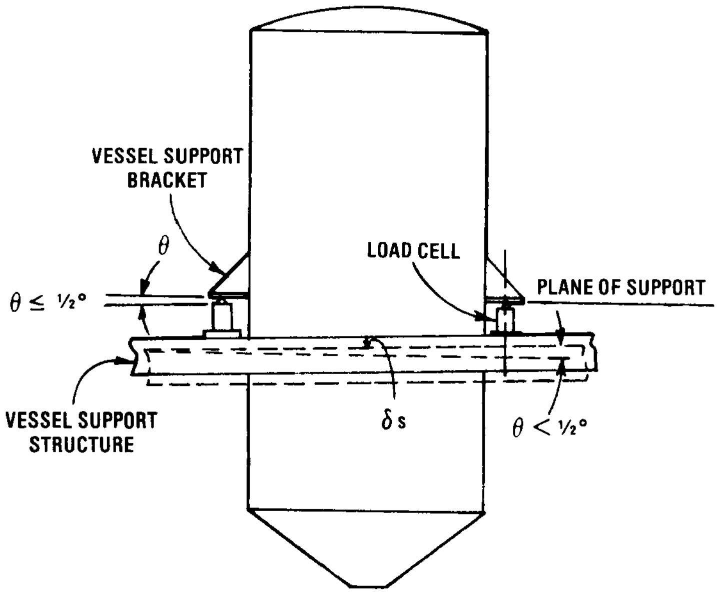
$$V = 450 \text{ lb} = 450 \text{ lb}$$

Discussion: The insertion of two standard universal joints in the 6- and 8-inch lines eliminates all possibility of nonlinear piping response on this weigh system.

Support deflection

UNDER GROSS VESSEL WEIGHT -

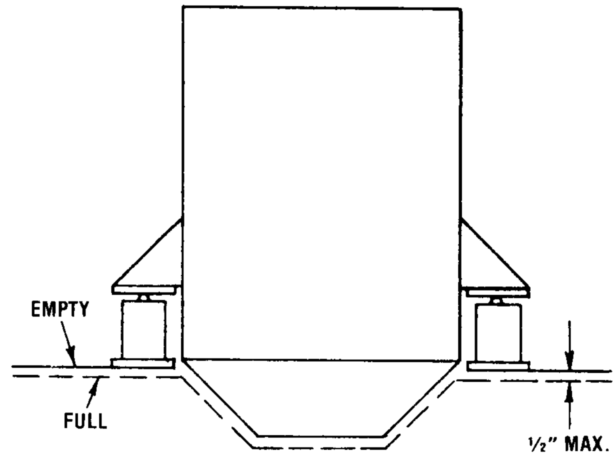
- Vessel support bracket should not tilt more than ½°
- Vessel support structure should deflect uniformly, generally less than ½ inch (12.70 mm)
- Vessel support plane should not tilt more than ½° due to any external event
- Load transducer support beam should not twist or warp more than ½°



SUPPORT DEFLECTION SHOULD BE LESS THAN ½ INCH (12.70 MM) UNDER GROSS VESSEL WEIGHT

System accuracy may be compromised by:

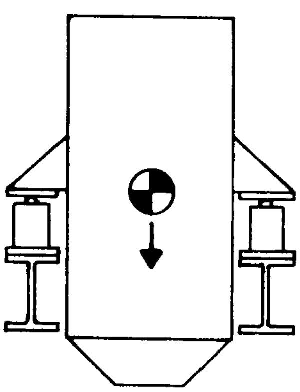
- Nonlinear mechanical restrictions when differential motions between vessel and piping or lateral restraint supports exceed design estimates
- Excessive vessel motion if "soft" support puts system resonance near frequency of pumps, agitators, traffic, wind gusts, or violent internal chemical reactions.



SUPPORT DEFLECTION SHOULD BE THE SAME AT ALL SUPPORT LOCATIONS -

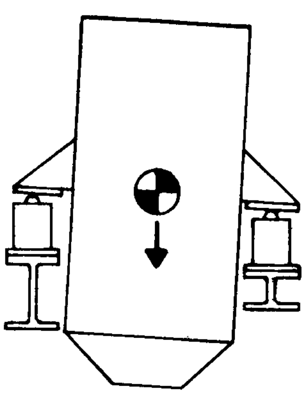
System accuracy may be compromised by:

- Nonlinear mechanical restrictions if a vessel
  - tilts with increasing load
  - rocks with agitation or chemical reaction



RIGHT

UNIFORM DEFLECTION, VESSEL STAYS PLUMB

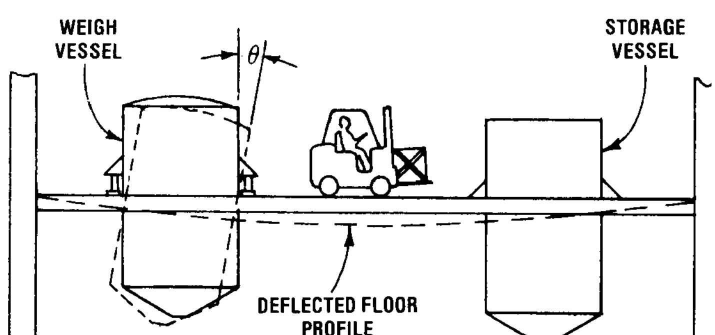


WRONG

VESSEL TILTS

THE VESSEL SUPPORT PLANE SHOULD NOT TILT MORE THAN ½° IN RESPONSE TO...

- Temporary events (forklift traffic, level changes in nearby vessels, etc)

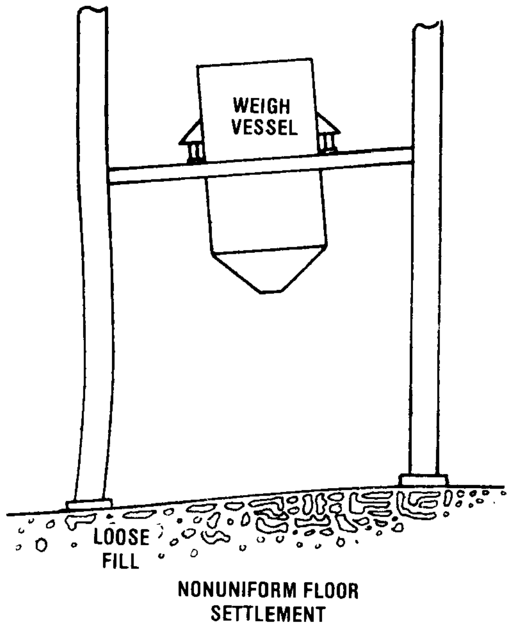


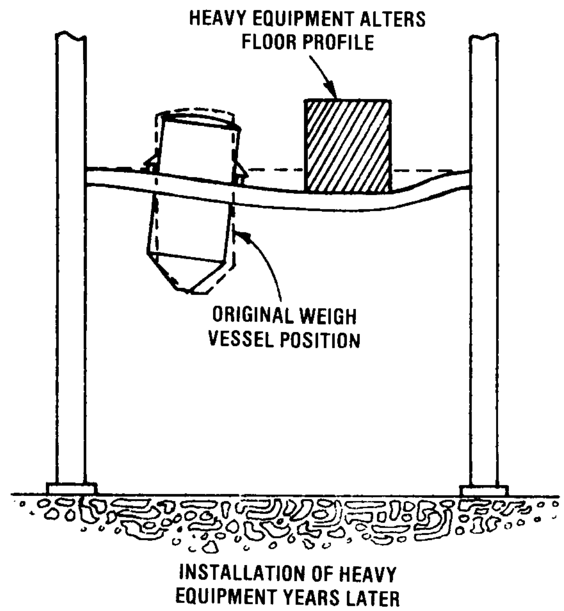
Support deflection (continued)

THE VESSEL SUPPORT PLANE SHOULD NOT TILT MORE THAN ½° IN RESPONSE TO...

- Permanent events

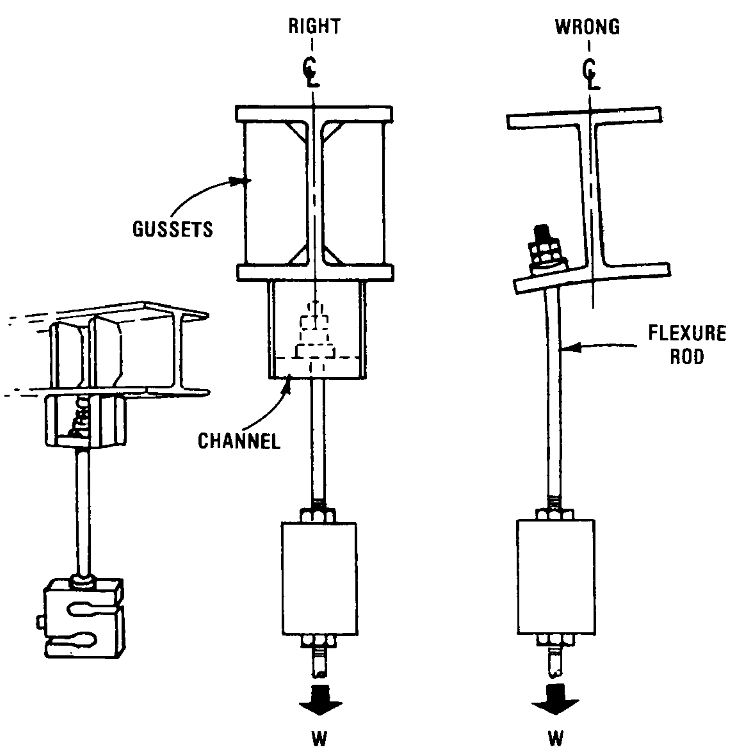
Tilting of the support plane causes a 'cosine error' in the load transducers, where signals decrease by 1/cos θ , θ being the tilt angle. The readout indicates less material than is actually in the vessel. Tilting is likely to create unanticipated mechanical restrictions as attached piping is displaced laterally by the vessel.

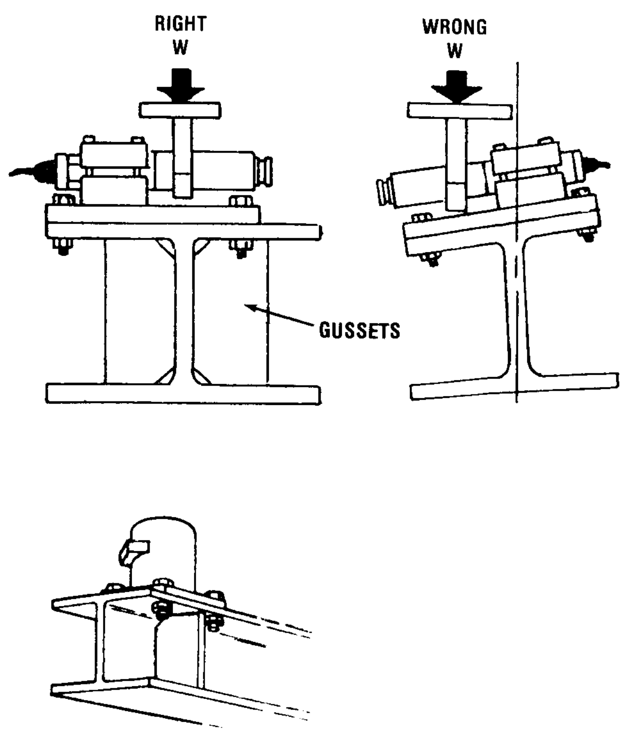




Load transducer/support beam alignment

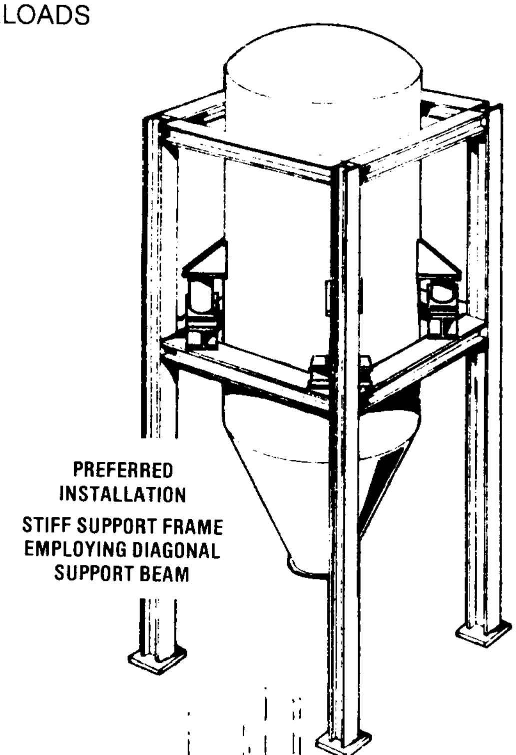
ALIGN LOAD CELL WITH BEAM CENTERLINE TO AVOID TWISTING OF BEAM WITH LOAD, SO THAT SYSTEM CALIBRATION ACCURACY IS NOT COMPROMISED.

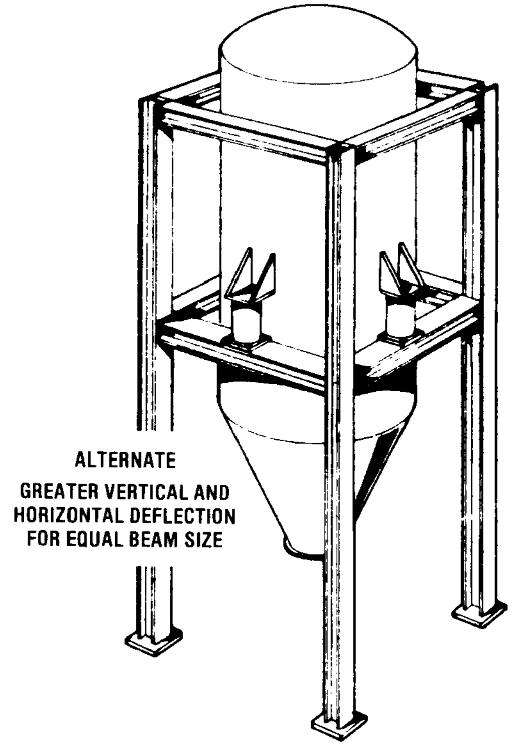


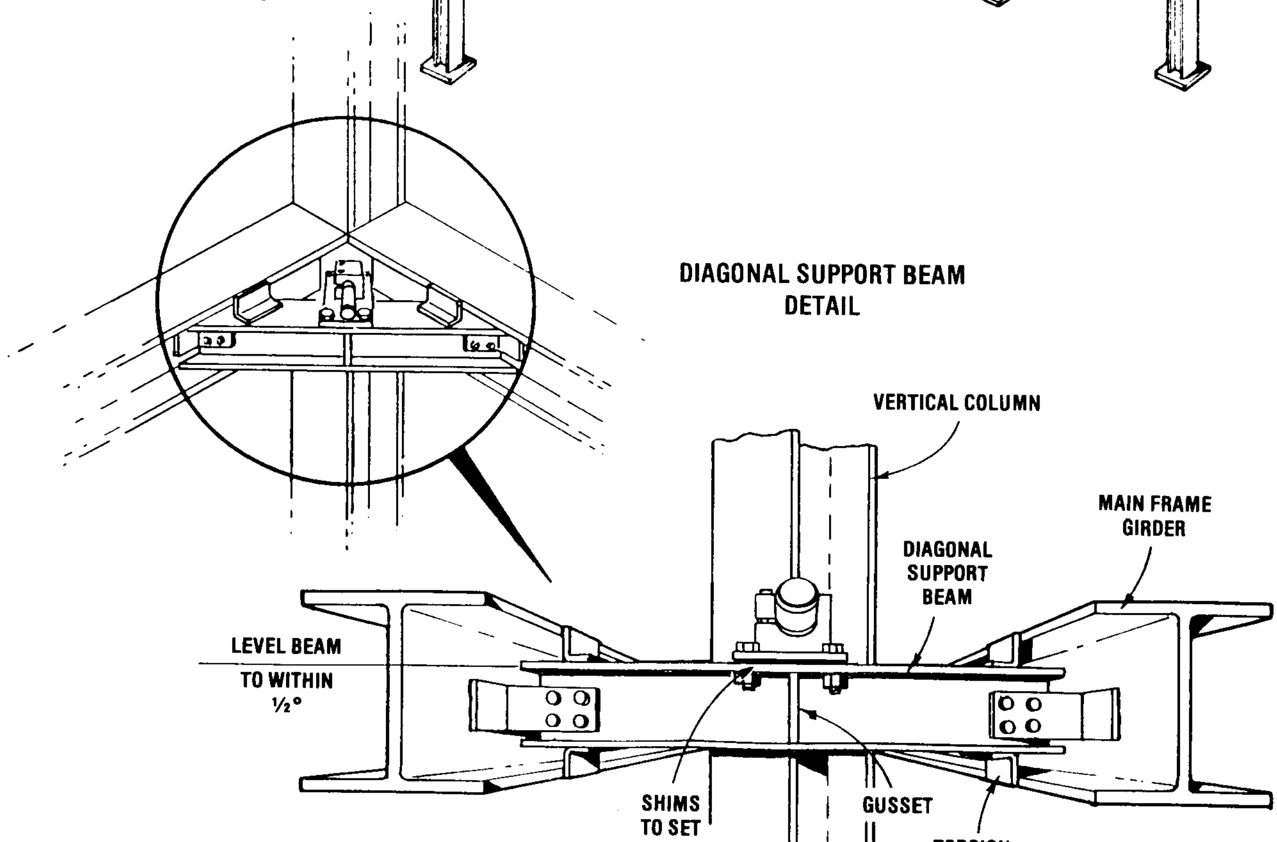


Diagonal beam support

LOCATE LOAD TRANSDUCERS CLOSE TO VERTICAL COLUMNS TO MINIMIZE SUPPORT DEFLECTION AND TILTING OF THE LOAD TRANSDUCER DUE TO SIDELOADS



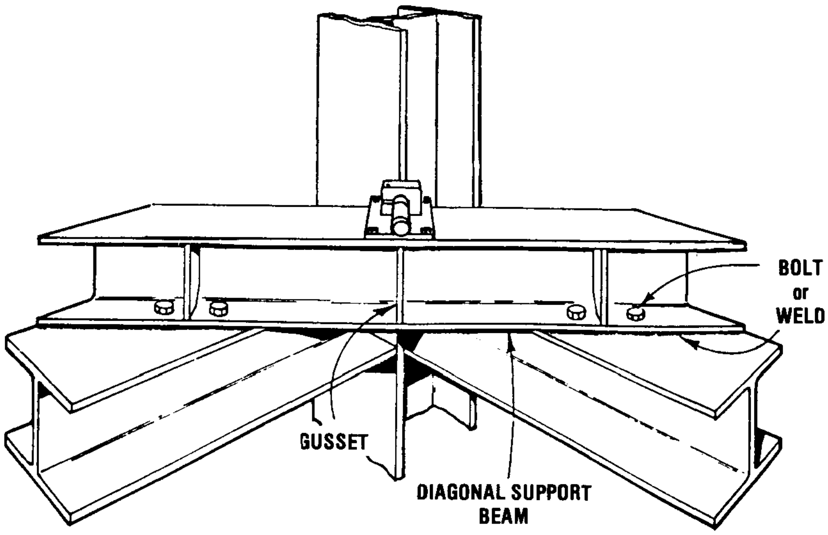




Diagonal beam support (continued)

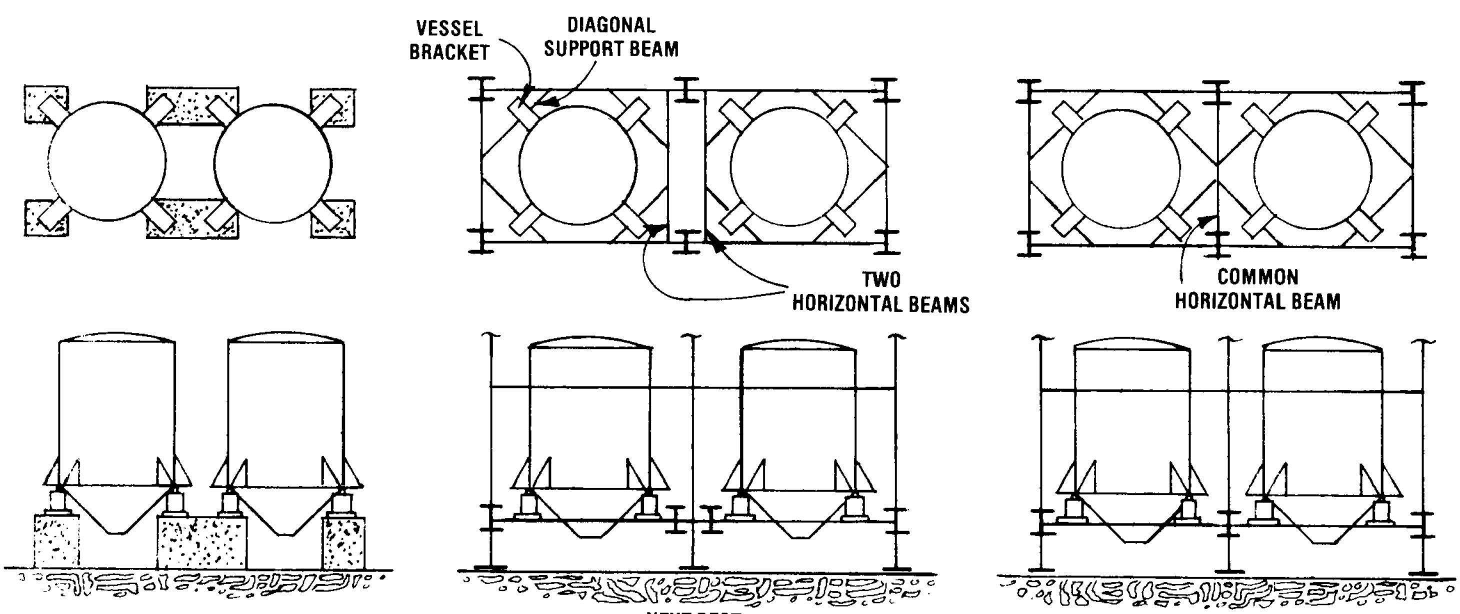
PERFERRED ARRANGEMENT

- Provide above floor access to facilitate load transducer installation
- Vessel weight carried safely in compression, not shear.
- Lateral restraint brackets may fit directly on the beam as well (Lateral restraints are usually not necessary for KIS beam installations)



Vessel interaction

When weighing adjacent vessels, structurally isolate one from the other to minimize cross-talk or interaction between them. Otherwise, weight changes in one vessel will affect the readout of the adjacent vessel.

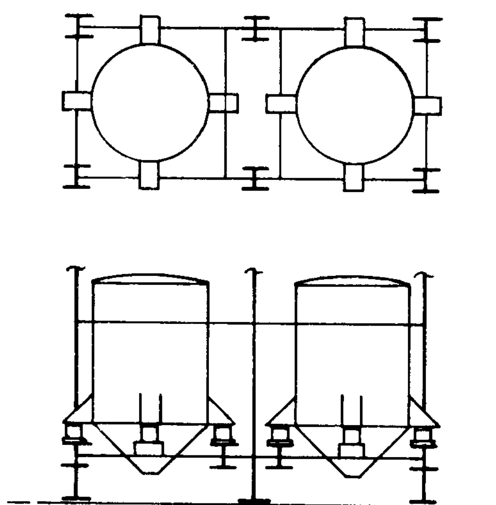


BEST
RIGID PIERS ON A FIRM FOUNDATION

NEXT BEST
SEPARATE SUPPORT FRAME FOR EACH VESSEL, ALL BEAMS SAME SIZE AND LENGTH

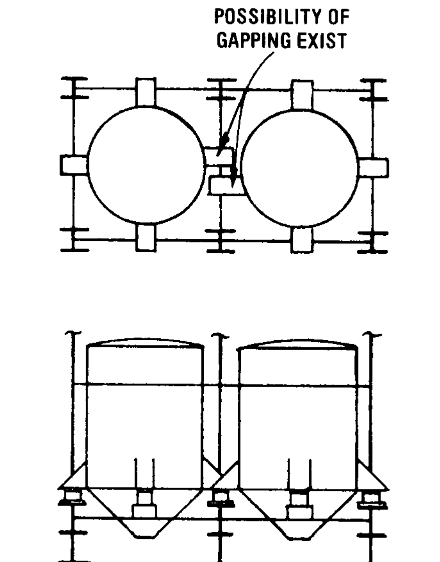
LESSER ALTERNATE
TWO VESSELS HAVE COMMON SUPPORT MEMBER

Vessel interaction (continued)



LESSER ALTERNATE

ALTHOUGH SEPARATE FRAMES, MIDSPAN SUPPORT BEAM DEFLECTION UNNECESSARILY LARGE

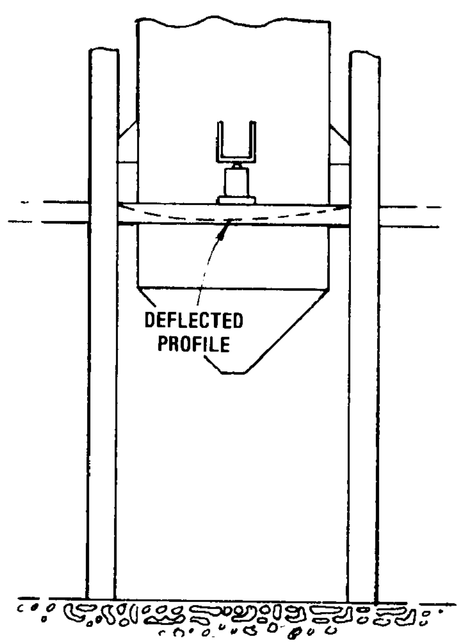


NOT RECOMMENDED

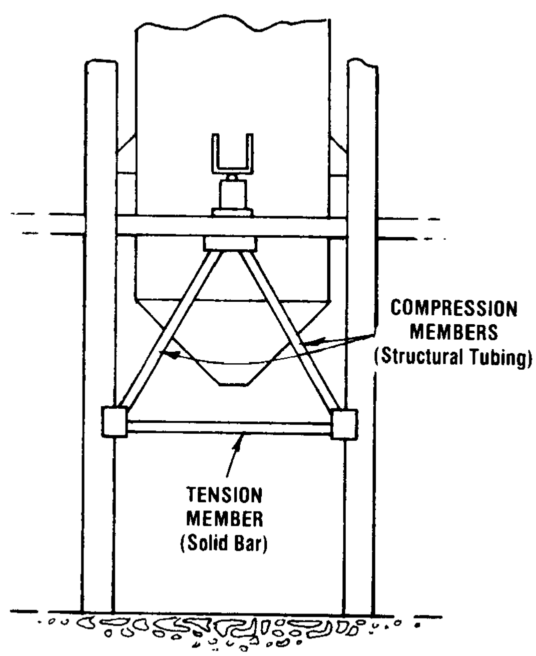
TWO VESSELS HAVE COMMON SUPPORT MEMBER; LOAD TRANSDUCER ON ONE VESSEL MAY GAP WHEN OTHER VESSEL LOADS UP

Stiffening existing structures

Excessive support structure deflections are undesirable for many reasons. (Refer to Vessel, Piping, and Support Deflections). Should it become necessary to stiffen an existing vessel support structure, the following suggestions may be of interest.

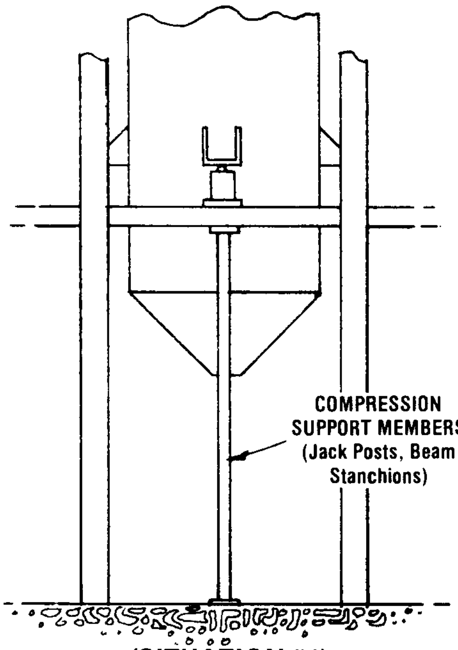


SITUATION #1
SUPPORT BEAMS UNIFORM AROUND VESSEL, BUT MIDSPAN DEFLECTION IS LARGE 1/16"

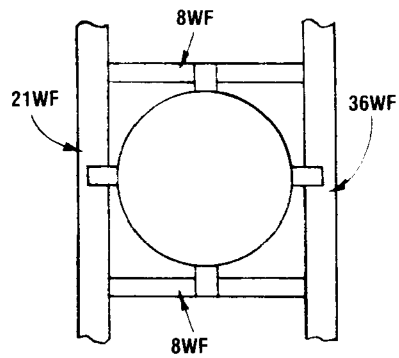


REMEDY #1

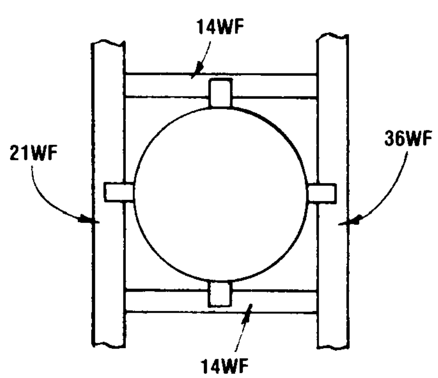
Stiffening existing structures (continued)



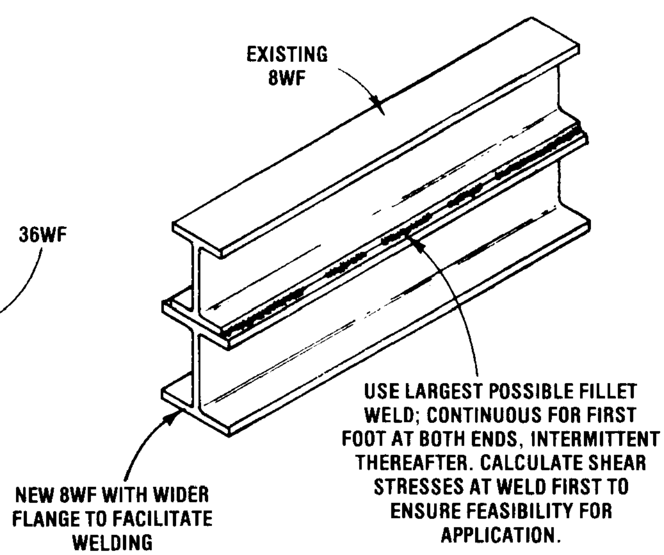
(SITUATION #1)
REMEDY #2



SITUATION #2
SUPPORT BEAMS NOT
UNIFORM, VESSEL ROCKS
ON LIGHT BEAMS



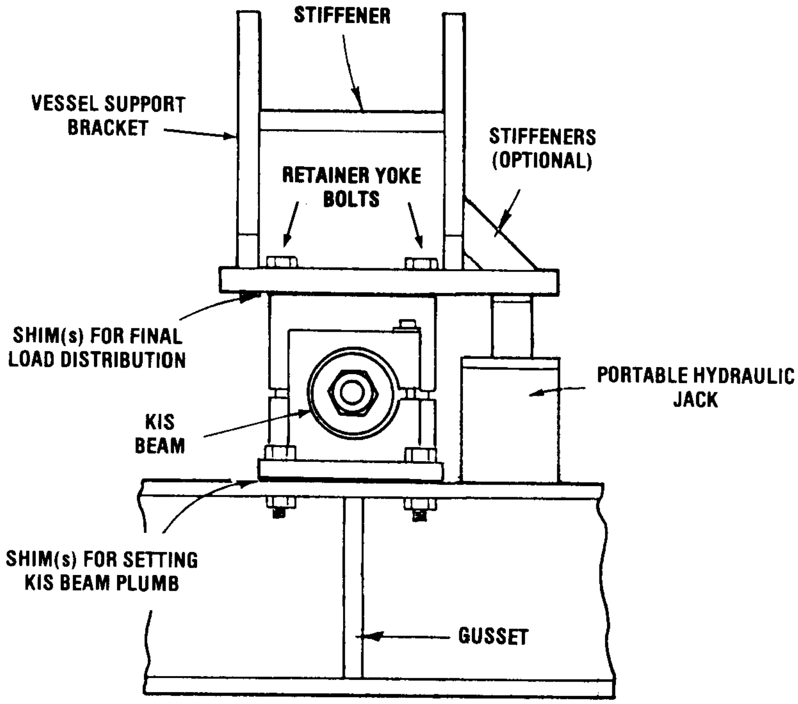
REMEDY #1
(Preferred)
REPLACE 8WF BEAMS
WITH STIFF 14WF

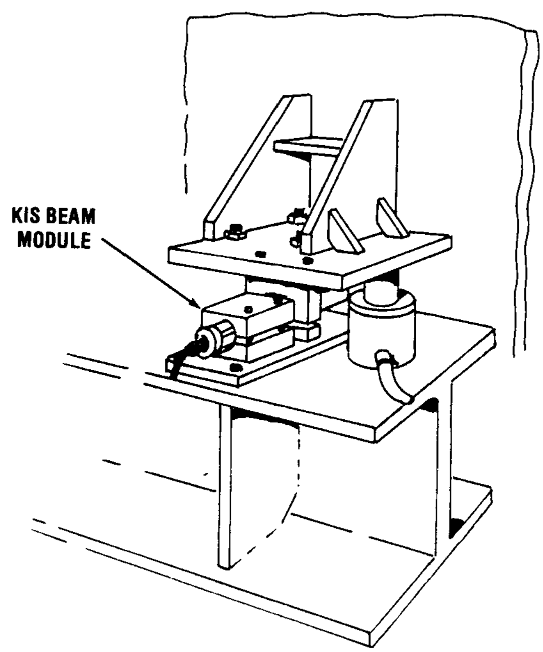


REMEDY #2
WELD ANOTHER BEAM
UNDER EACH EXISTING
8WF BEAM

Support details - KIS beams

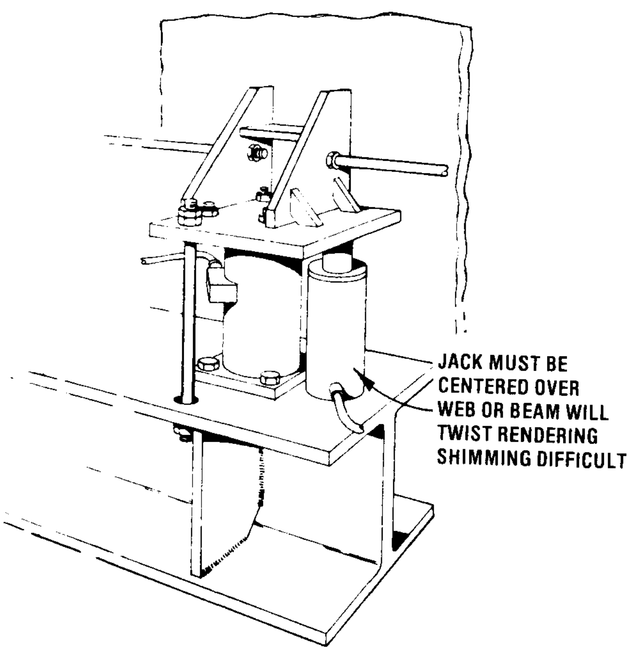
- Retainer yoke assembly bolts directly to vessel support bracket
- Stay rods typically not necessary
- Vertical restraint rods typically not necessary
- Provision for jacking (simplifies installation, maintenance and field calibration)

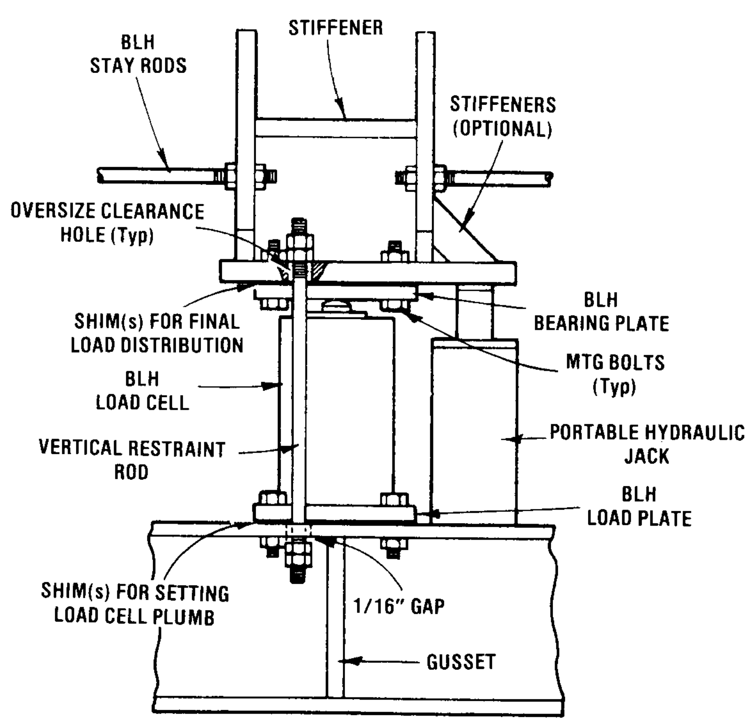




Support details - compression load cells

- Preferred stay rod arrangement
- Provision for jacking (simplifies installation, maintenance, and field calibration)
- Vertical restraint rod (used when safety check rods cannot be installed at other elevations)





Support details - tension load or S-cells

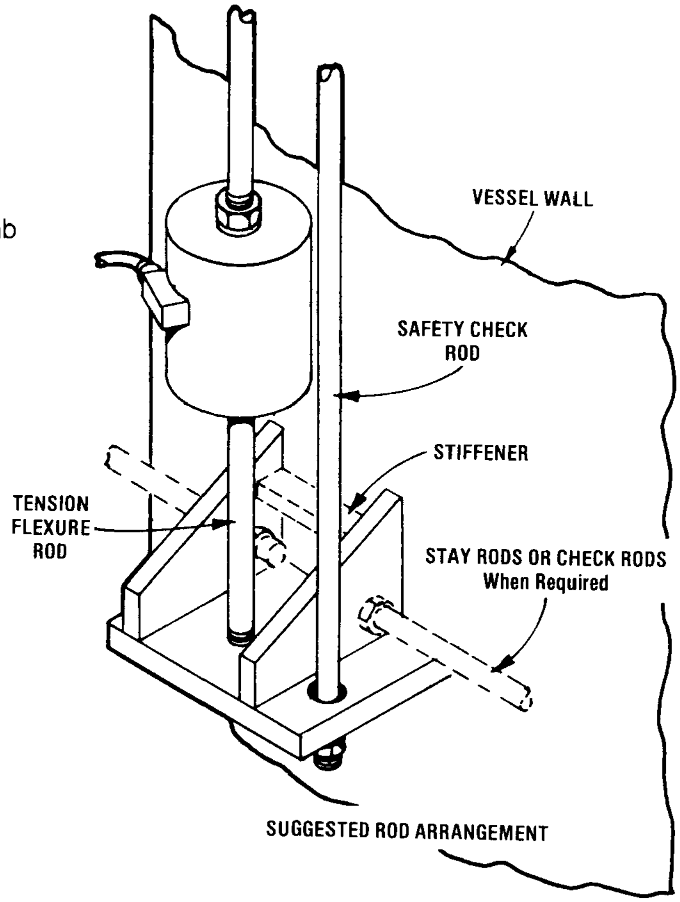
THE CHECK ROD ALSO SERVES AS -

AN INSTALLATION TOOL:

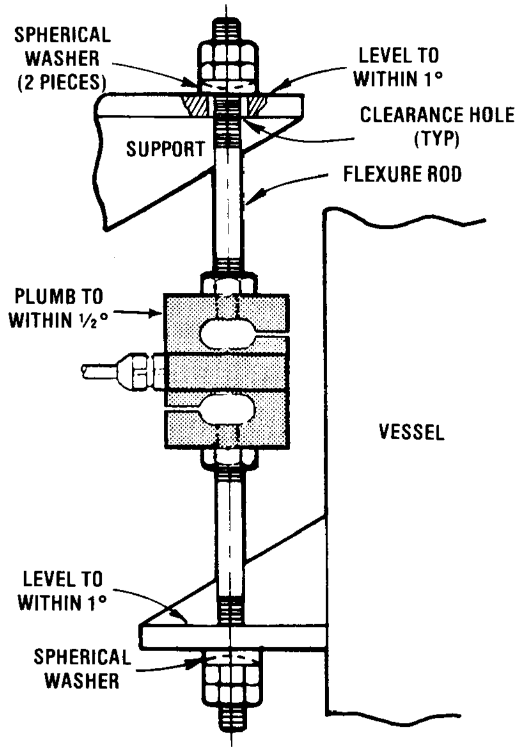
- Hang vessel on check rods at proper height
- Make all piping connections, weld, insulate, etc
- Install tension cells and flexure rods, set plumb
- Back off nuts on check rod so tension cells support vessel
- Set gap on check rods and lock up nuts

A SERVICE TOOL:

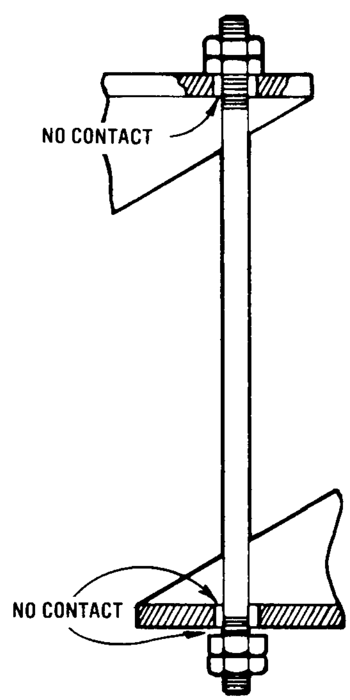
- Check rods can be again used for vessel support
  - -should vessel need repairs or modifications (protect tension cells from mechanical impact)
  - -should tension cells ever need repairs



SUGGESTED ROD ARRANGEMENT



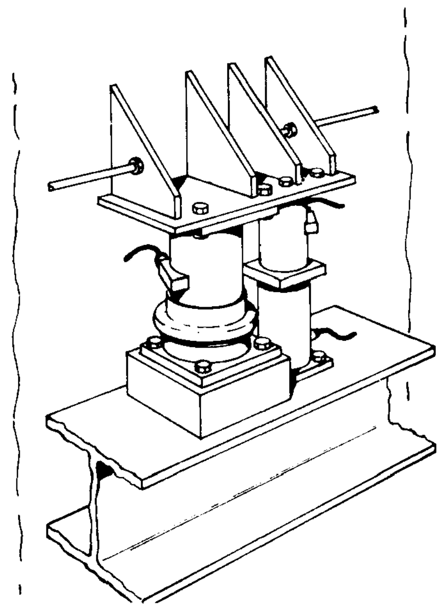
TENSION FLEXURE ROD



SAFETY CHECK ROD

Hydraulic calibration arrangement

PREFERRED TECHNIQUE: Calibration unit removes live load from permanent load transducer



- **Operating procedure**

  Zero both systems.

  Fill vessel to capacity with product.

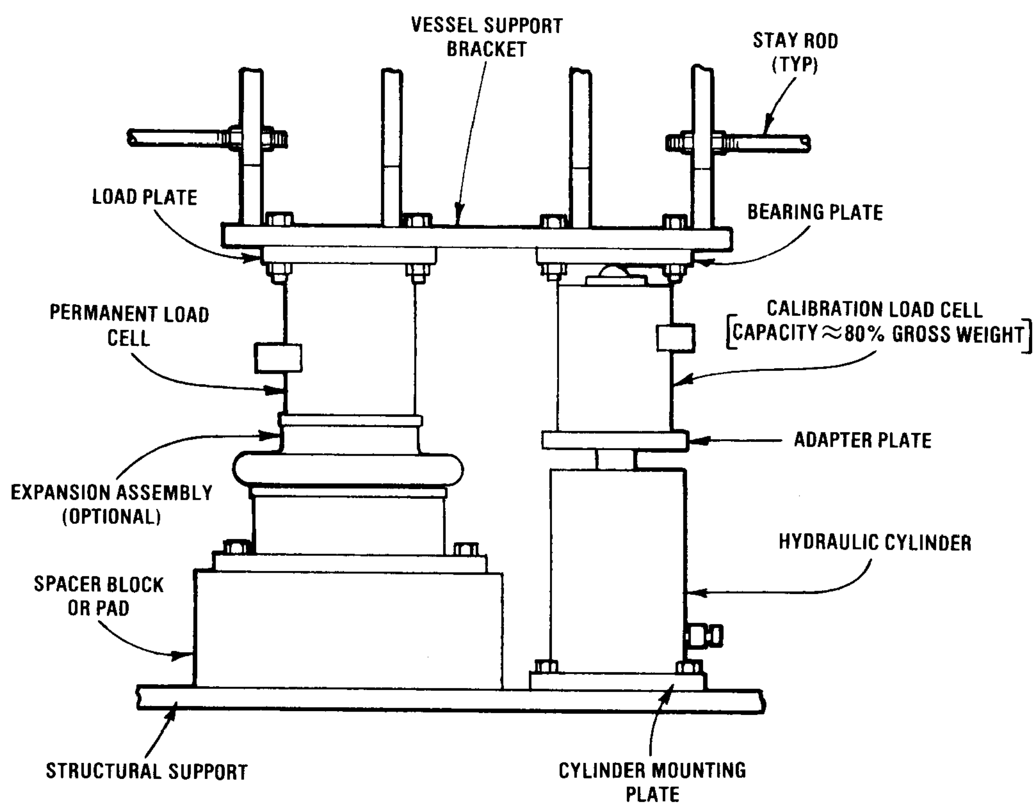
  Jack calibration cylinder until it carries 80% of gross weight or maximum live load. (This limit prevents gapping on the permanent load transducer.)

  Bleed cylinder to reduce load on calibration cell in convenient increments. (Provide for individual operations of each cylinder since vessel weight is generally not equal on all supports and performance differs slightly among cylinders.)

- **Advantages**

  The effects of vessel deformation under live load — load redistribution, wall distortion, support bracket tilt, vessel elongation — will be observed and, if necessary, corrected.

  No extra structural members or devices are required to support the calibration unit.



General rules

- A free-standing vessel fully supported by load transducers on firm suports has a weigh system accuracy approaching that of the load transducers and the instrumentation alone, a value well below 0.1%. Experience has shown the one factor most often compromising weigh system accuracy to be the mechanical restriction arising from piping connections with insufficient flexibility or displacement capability.
- To minimize these problems, BLH Electronics recommends that all piping attachments to the vessel be made as flexible as process materials and temperature will allow, specifically:

  On high pressure systems (> 25 psi), use schedule 10 (or 5) stainless steel pipe instead of schedule 40 carbon steel for a 150 - 300% increase in flexibility on the final run to the vessel. Filament-wound, glass-reinforced piping is suitable for applications up to 200°F and 125 psi when the process chemistry allows. Expansion joints and universal joints with adequate pressure ratings, both metallic and nonmetallic, are also recommended provided that they are positioned horizontally to avoid vertical thrust forces.

  On low pressure systems (< 25 psi), use nonmetallic flexible piping devices whenever possible. Major suppliers now carry Teflon, elastomers, and plastics, all at least three times less stiff and often more wear resistent than the metallic counterparts. Be aware that metallic components covered with metal braid are sources of frictional, hysteresis-type forces due to the contact between the metal bellows and braid; in one test, a horizontally installed 2" diameter metallic expansion joint was shown to alter vessel output by 50 lbs (22.7 kg) depending upon the initial offset of the joint before the calibration run.

  Be careful when using forces and deflections calculated by computer for vessel and piping. Experience has shown such values to be generally oblivious to the significant vessel-support and piping-support deflections encountered in the field. Refer to 'Accuracy Vessel Piping, and Support Deflection' (p. 35) for often ignored deflection sources.

  Support the piping from the same floor the vessel rests upon; do this at least for the support closest to the vessel. This tends to minimize differential thermal expansion and differential support (floor-to-floor) deflection problems between piping and vessel. Refer to Special Design Considerations, 'Piping Flexibility', for supportive discussions.

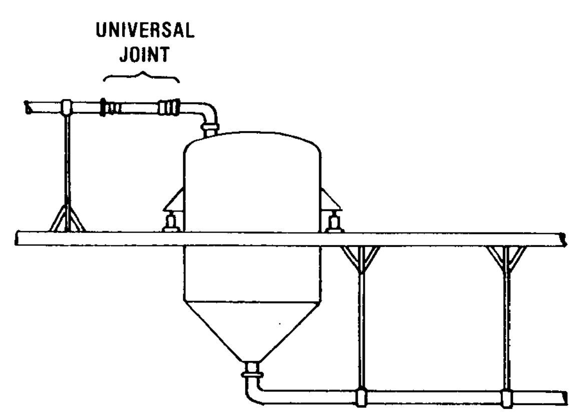
  For minimum piping restriction, consider cold-springing all piping at fitup so that the mating flanges on piping and vessel align freely before being bolted together. This would be particularly beneficial on lighter weigh vessels.

  All piping tends to sag from its theoretical (design) position due to its own dead weight, exterior insulation, and live contents. It is therefore good to practice to inspect all piping runs between weigh vessel and first pipe support for adequate clearance around each line; a minimum space of 1 inch (25.4 mm) should exist between any given pipe and another pipe, steelwork, ductwork, etc. All too often, field installation crews fitting and insulating pipes violate the intended spacial geometries leaving only narrow gaps between lines which become sources for nonlinear mechanical restriction to the weigh vessel.

Sealed systems

- **FLEXIBLE PIPING DEVICES (Expansion joints, universal joints, flexible couplings; flexible hoses and ducts)**

  Locate these devices in horizontal piping runs adjacent to the weigh vessel to avoid vertical thrust forces from varying internal pressures associated with material flow and process chemistry. It is preferrable to have these forces act laterally where they translate into minor horizontal forces and insignificant overturning moments on the vessel.



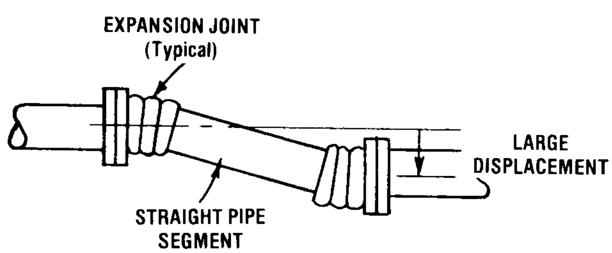
RECOMMENDED PIPE
SUPPORT ARRANGEMENT

Sealed systems (continued)

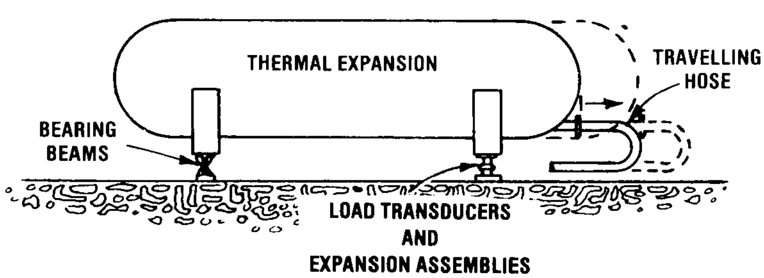
- **FLEXIBLE PIPING DEVICES (Expansion joints, universal joints, flexible couplings; flexible hoses and ducts) (continued)**

Do not stretch or compress these units excessively or use them to compensate for initial piping misalignments at fitup, lest their stiffness characteristics be altered. Above all, if flexible devices are used vertically, do not rest the vessel upon them and then install the primary vessel supports with the vessel in that position...this field installation practice is not uncommon on smaller vessels. Obviously, a corrugated device will lose much of its flexibility when tightly compressed.

Where large displacements must be accommodated with low force, use hose for the final leg to the vessel. If this is not practical, consider using two expansion joints or flexible couplings in a series as a "universal joint", or a flexible hose bent U-shaped as a "travelling hose". This is particularly important for low capacity systems where even small piping forces will disturb weigh system stability.

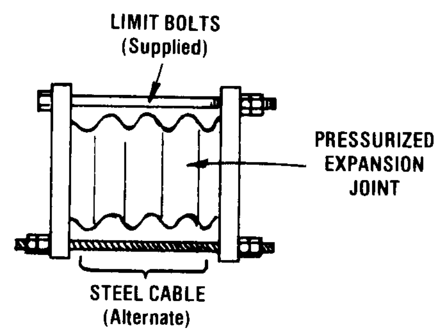


UNIVERSAL JOINT



Do not use rigid insulation on expansion joints and flexible hoses or their lateral flexibility will be compromised; use heat-trace cable instead.

In some systems, process pressure is high enough to force expansion joint flanges tight against limit bolts (supplied for that purpose). If joint length is short compared to diameter, perhaps 1:1 or less, joint flexibility may be compromised by friction of bolts against flanges. Lateral flexibility may be restored, however, if limit bolts are replaced with properly terminated steel cable of equivalent tensile strength. This "fix" should not be necessary in a properly designed system; it is mentioned here as a means of improving the flexibility of existing piping in a retrofit installation.



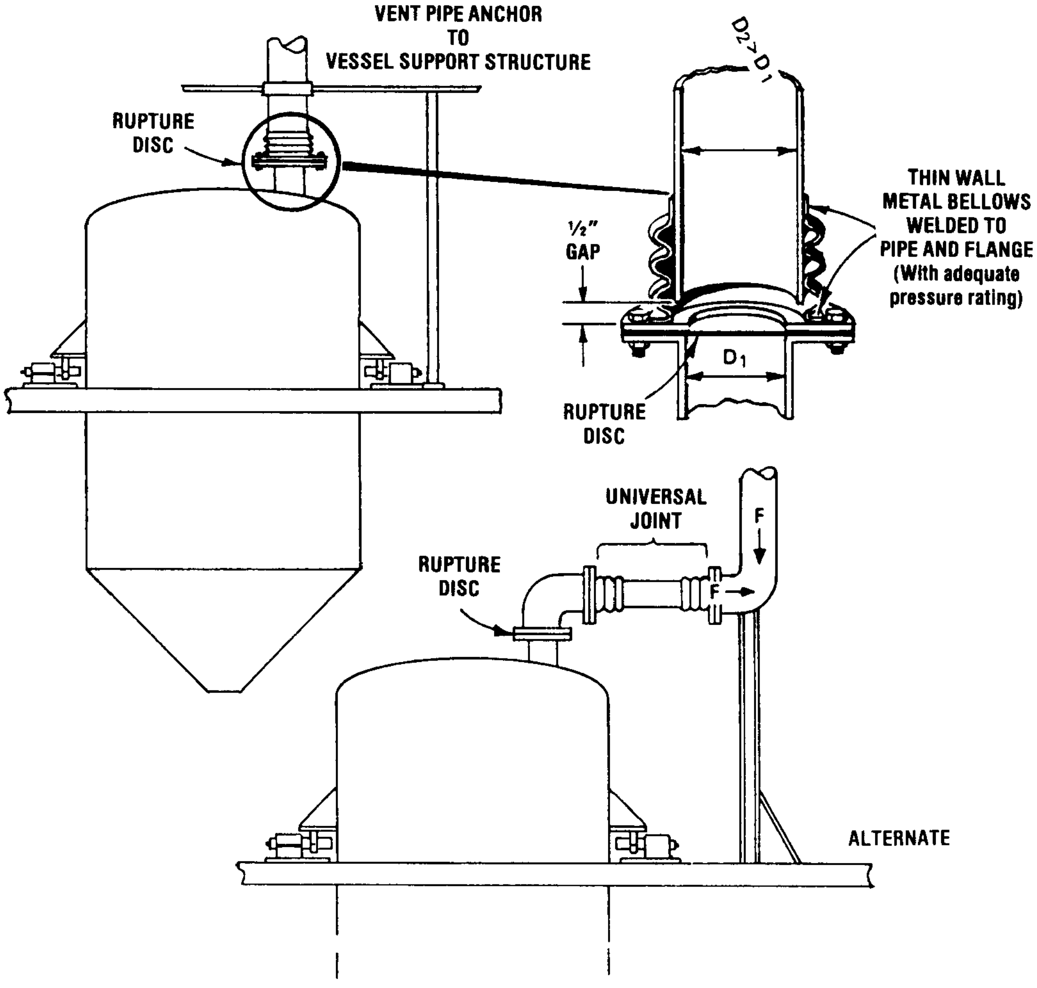
A more frequent problem occurs when short flexible devices absorb the torque acting about the pipe axis and "wind up" until the limit bolts jam tight. The resultant loss of flexibility may impair weigh system accuracy particularly if dead weight calibration had been performed with the system cold, before the pipe rotation occurred. If possible, install a pipe guide ahead of the flexible joint to arrest the rotation. Failing that, a simpler "fix" may be to loosen the bolts. This will reduce the stiffness somewhat, but not entirely, due to the continued torque imposed on the joint.

Flexible devices of nonmetallic materials offer more flexibility in less space and with less vibration transmission than metal counterparts. These benefits plus, variously, increased wear, corrosion and fatigue resistance makes nonmetallics highly attractive when the process pressure and temperature requirements can be met.

piping design

Sealed systems (continued)

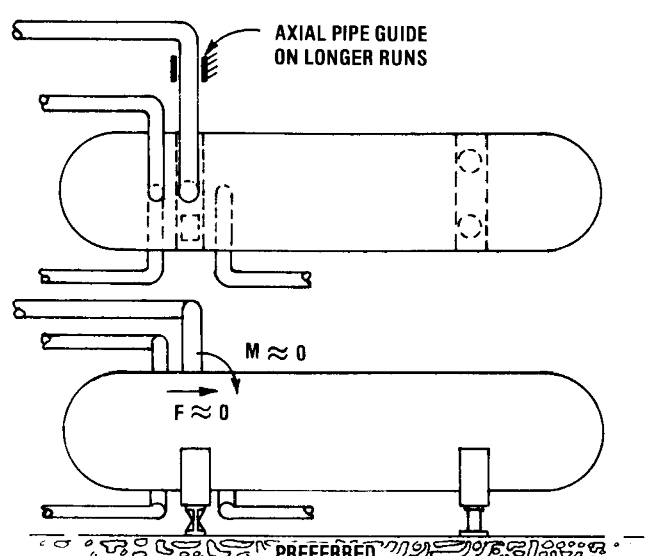
- VENT (BLOW DOWN) LINES



- **HORIZONTAL TANKS ON LOAD TRANSDUCERS AND BEARING BEAMS**

Locate as many of the piping attachments as practical in the vicinity of the bearing beam. This minimizes the vertical piping forces seen by the load transducers, since pipes then act over the fulcrum of the vessel.

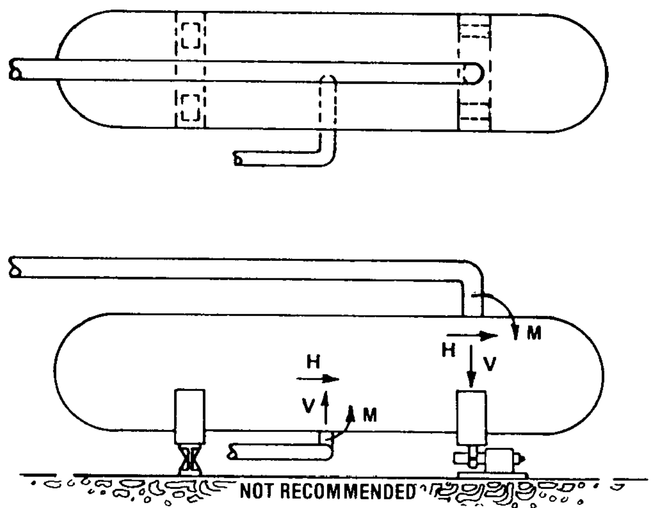
Orient last piping runs transverse to vessel to minimize effect of piping expansion on the weigh system. Expansion forces will then tend to cause minor overturning moments about the tank axis with little effect on weigh system output.



Cluster piping over beam. Bring lines in transverse to vessel axis.

Sealed systems (continued)

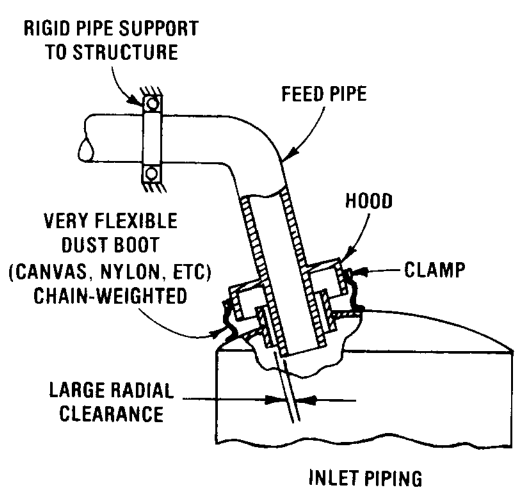
- **HORIZONTAL TANKS ON LOAD TRANSDUCERS AND BEARING BEAMS (continued)**

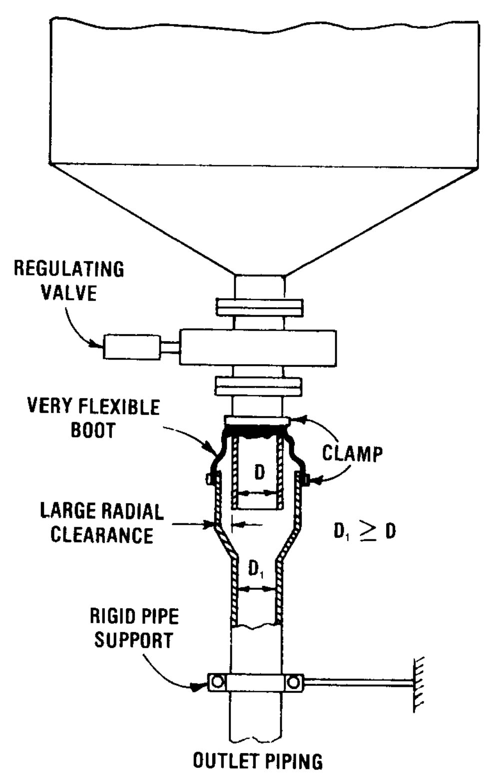


Vented systems

- **ATTACHMENT DETAILS**

Achieve maximum weigh system accuracy by eliminating piping interactions entirely...feed piping through clearance ports in the vessel, covering gaps with very flexible dust boots. Support all such piping from structure just beyond the vessel.





vessel design

General rules

- **Vessel support brackets**

Locate support brackets at the maximum vessel center-of-gravity elevation whenever convenient. The vessel is then inherently stable and the need for lateral restraints away from the plane of support (i.e., safety check rods) is minimized.

Restrict angular deformation of the support bracket under gross vessel weight to less than ½° when a compression load transducer is mounted on the vessel bracket, less than 2° when mating accessory is mounted on the bracket, to avoid compromising system accuracy. (Brackets on unweighed vessels are usually bolted down, so designing a vessel wall for stiffness to minimize local bracket deflection is not normally considered; now it should be.)

Design the support brackets to accommodate some means of jacking the vessel to ease load transducer installation and maintenance. Refer to 'Structural Design' for design suggestions.

Do not position the brackets so that load transducer installation and maintenance is impeded by concrete or limited access space with attendant loss of time and increased expense.

- **Process heating systems**

Do not use steam or heated gas in a jacketed vessel when hot oil or water will do, and avoid the adverse effect of variable buoyancy with temperature and pressure on in-process system accuracy.

- **Vessels with agitators**

When the weight of an agitator motor and mount is an appreciable portion of the gross vessel weight, locate the apparatus on the vessel for the most uniform weight distribution among the supporting load transducers. This not only facilitates vessel handling and reduces the overload hazard to one or two load transducers, but permits the use of lower capacity load transducers (with more signal output) for better weigh system resolution.

The stability of the weigh system will be enhanced if internal baffles or counter-rotating agitator blades are used to reduce fluid slosh.

- **Lifting lugs for calibration weights**

Specify weight lifting lugs on those vessels requiring periodic dead weight calibration. Locate one lug per load transducer near the base of the vessel to accommodate the jacking device (chain fall and come-along) and dead weight blocks. Position the lugs symmetrically around the vessel perimeter while maintaining adequate clearances from the surroundingequipment for jacking weights. A common arrangement is to align the lugs with the load transducer positions, so that tipping of the vessel is precluded -- a real possibility on smaller vessels with three supports or less.

Design the lugs to carry 10% of gross vessel weight when the dead weight/material substitution method is to be used; design the lugs for their share of the total live load if calibration is by dead weights alone.

- **Saddle supports for horizontal tanks on load transducers and bearing beams**

For maximum weigh system accuracy when mechanical field calibration will not be used, position supports symmetrically on the tank so that the approximate load fraction seen by the load transducers is known and will not change with load.

- **Vessel tare-to-live weight ratio**

Minimize the ratio of tare weight to live weight for the most stable signal. As indicated earlier, the general rule of thumb for selection of load transducer capacity is to obtain 1.0 mV/V output over the range of live load. In most installations, this is assured since the vessel tare weight is perhaps 10% - 30% of the gross weight; a load transducer with 2.0 mV/V output will easily provide the necessary signal for a high accuracy system. On the other hand, a system consisting of a thermally-jacketed, agitated and nonsymmetric vessel weighing some 5000 pounds with rigid jacketed piping connections cannot sense a 300 pound live load with great precision; the 'live' signal must be amplified to the point where line noise and normally trivial temperature effects now become significant.

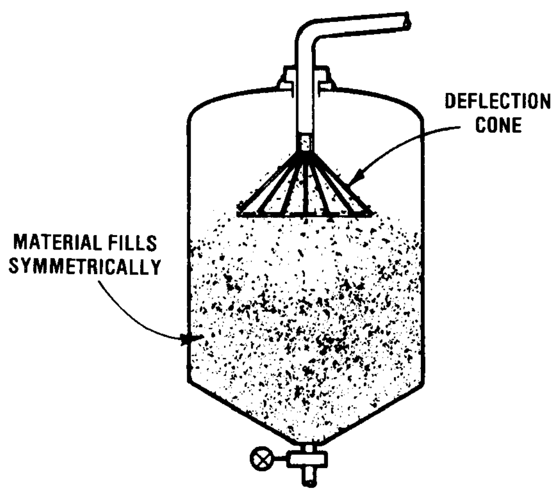
General rules (continued)

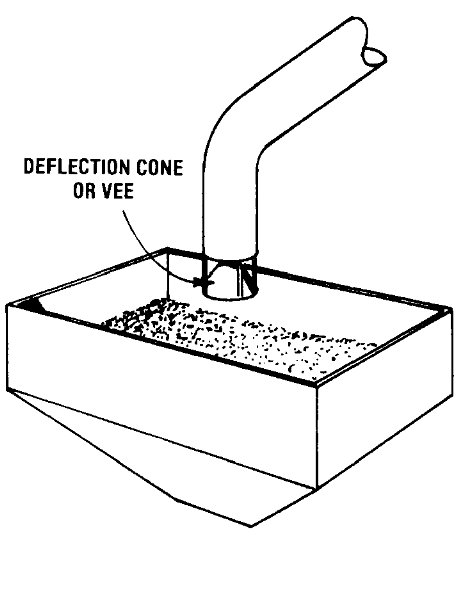
- **Vessel tare -to-live weight ratio (continued)**

Consult BLH Electronics for recommendations if a high tare weight appears inevitable, since electronic techniques can be employed to increase system accuracy at low signal levels.

- **Vessels with non-level material**

Design inlet and outlet ports for symmetric loading and unloading of material. Doing so aids weigh system accuracy by keeping the load on the transducers uniform and, therefore, the support deflections more uniform. The former minimizes the already-small error due to variation in load transducer characteristics; the latter reduces the likelihood of mechanical restrictions due to vessel tilt.





- **Vessels suspended by single tension cell**

If lateral restraints are not present on the weigh vessel, one or more swivels should be included in the tension linkage to accommodate the modest vessel rotation that usually occurs without applying a torsional moment to the tension cell. Torque on the tension cell will produce a small, but variable error in the system readout.

Experience has shown that most system designers do not properly size the support structure to keep the vessel deflection at gross weight under $\frac{1}{16}$". Ignoring this will probably generate several deflection-induced problems.

- **Vessels located in traffic areas**

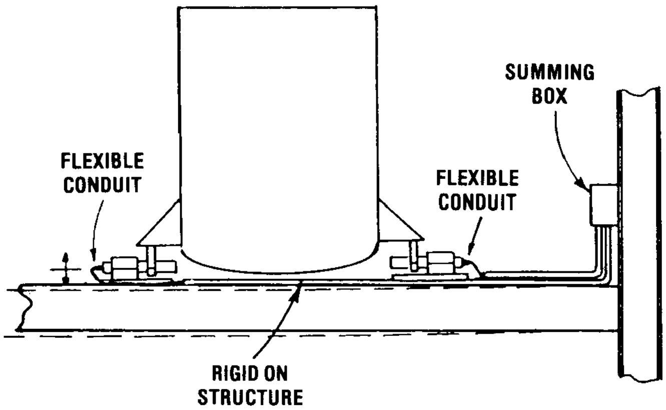
It is good practice to construct protective piers or barriers on the traffic side of weigh vessel supports to preclude system shutdown, however temporary, from accidental impact.

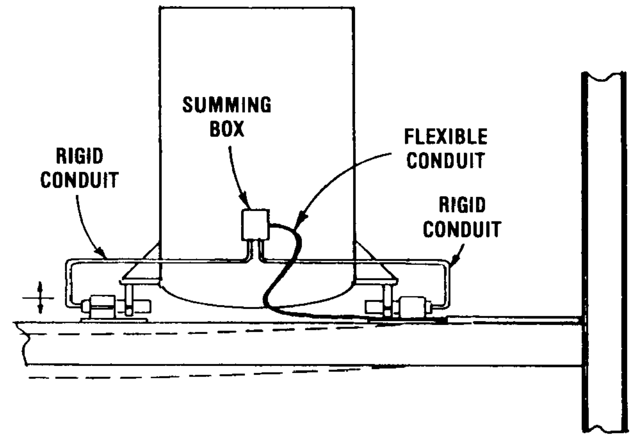
wiring design

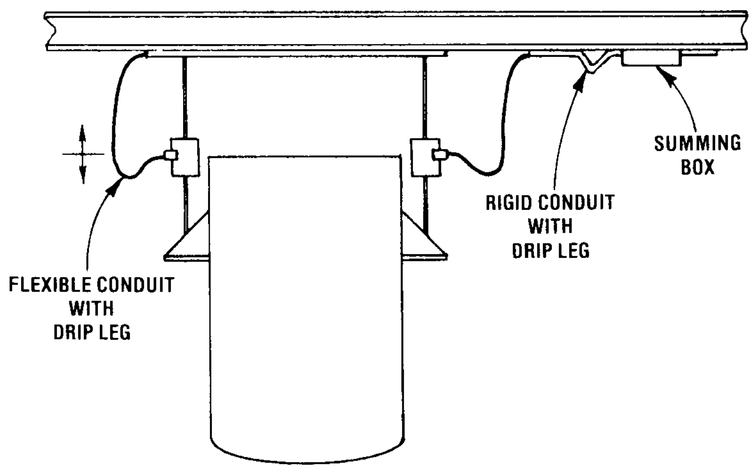
General rules

- Improper wiring details can sometimes generate mechanical restrictions to the weigh vessel or cause system calibration errors. Adherence to the following should avoid such problems.

  USE FLEXIBLE CONDUIT between the moving load transducer (or vessel) and the stationary support structure. It is good practice to provide a drip leg to prevent moisture or chemical accumulation at cable entry or conductor, particularly in wash down areas or outdoor installations. To prevent flexible conduit from being streched taught by the installation crew with attendant loss of flexibility, specify a 360° loop in the conduit.







  DO NOT SHORTEN THE LOAD TRANSDUCER CABLE or load transducer calibration will be needlessly altered. Instead, coil the excess outside the summing junction box, or where conduit is required, inside the summing box or inside an otherwise empty box adjacent to it. When longer cable lengths are required, order additional extension junction boxes and the necessary length of four-conductor cable. Increasing cable length on individual load transducers up to 25 feet (7.62 m) will not add significant error to the system.

Where cables must be lengthened to fit, load transducer output will be altered. It will decrease by 0.03% (0.1 ohm/350 ohms) for every ten feet of cable added when the load transducer is operating at a constant 70°F. As the operating temperature rises above 70°, transducer output will decrease further by 0.006%/100°F for every ten feet added. These known (not random) errors in individual load transducers are additive in their total affect upon the weigh system.

Example 1a: Four load transducers are ordered with standard 10 feet of integral cable. Two cables are subsequently lengthened five feet apiece. The load transducers operate at the constant ambient temperature of 70°F.

Error Analysis: If weigh vessel is to be dead weight calibrated, no system errors result from modifying the cable. If weigh vessel is to be calibrated electronically, or

General rules (continued)

Example 1a, Error Analysis (continued)

not at all, system output will be reduced by 0.015% in both transducers for a total span loss of 0.030%. The readout instrument may be adjusted by this amount to compensate.

Example 1b: Assume that ambient temperature surrounding the above load transducers cycles between 70°F and 120°F.

Error Analysis: In addition to errors discussed in Example 1a, the output of both transducers with lengthened 15 foot cables will decrease 0.0015% apiece, for a total system readout error of 0.003% at 120°F. For most systems this error is insignificant.