Piping Design

Any time that piping is connected to a tank scale (a dead-to-live connection), there is a potential for mechanical binding. If piping is not installed properly, it can cause weighing errors by pushing or pulling on the tank. The best way to avoid those problems is to design piping so that it does not exert unwanted forces on a tank. Here are some general guidelines you should follow when designing a piping system:

- Make sure the tank's support structure deflects as little as possible. That will decrease the amount of deflection in the piping.
- Run all pipes horizontally from the tank so that the tank is not suspended by the piping.
- Locate the first rigid support for the piping as far away from the tank as possible. That will make the piping more flexible.
- Use pipe with the smallest diameter and lightest gauge possible. That will make the piping more flexible.
- Use flexible piping or connections whenever possible.

Why is it important for piping to be flexible? Figure 5-20a shows a tank mounted on weigh modules and supported by an I-beam. A pipe is connected to the tank and rigidly clamped to another structure at a distance (*L)* from the tank. When the tank is empty, the pipe remains in a horizontal position and exerts no force on the tank. When the tank is full (see Figure 5-20b), it moves downward because of the deflection of the load cell and the I-beam. This pulls the pipe downward the same distance that the tank deflects (Δh). The pipe exerts an upward force on the tank, affecting weight measurements. The more flexible the piping is, the less force it exerts on the tank.

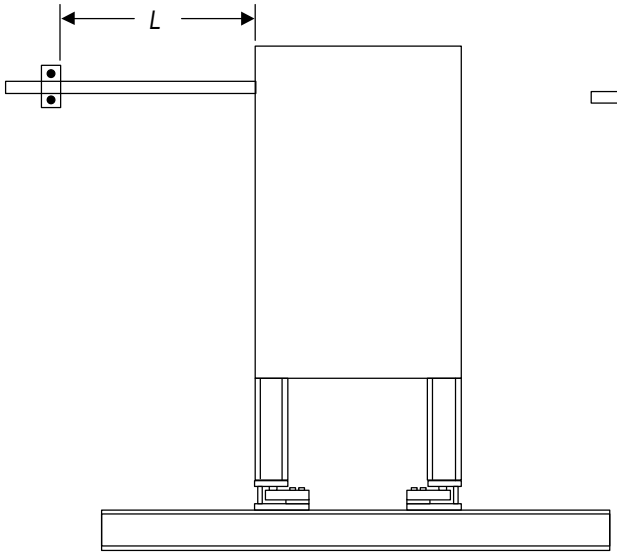


Figure 5-20a: Empty Tank

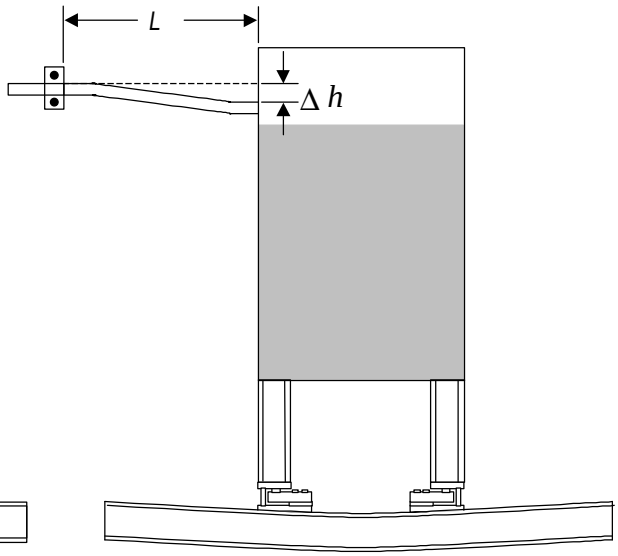


Figure 5-20b: Full Tank

Piping can have a significant effect on weighing accuracy, especially when many pipes are connected to a tank with a relatively low capacity. By designing the piping properly, you can reduce unwanted forces to a fraction of the tank's live load. Then you can compensate for the remaining forces when you calibrate the scale. Since load cell simulators cannot simulate the forces produced by attached piping, calibration must be performed on the installed tank scale.

You can use the following equation to calculate the force exerted by an attached pipe:

$$F_P = \frac{0.59 \times (D^4 - d^4) \times Dh \times E}{L^3}$$

where:

F_P = Force exerted by pipe

D = Outside diameter of pipe

d = Inside diameter of pipe

Δh = Total deflection of pipe at the vessel relative to the fixed point
Total deflection equals the load cell deflection plus support deflection
(see Appendix 7 for load cell deflection data)

E = Young's modulus

L = Length of pipe from the vessel to the first support point

The value of E (Young's modulus) varies for different types of material. Three common values are listed below:

- Carbon Steel = 29,000,000 lb/inch^2 (29×10^6)
- Stainless Steel = 28,000,000 lb/inch^2 (28×10^6)
- Aluminum = 10,000,000 lb/inch^2 (10×10^6)

The equation assumes a rigid connection at both ends of the piping, which is generally conservative. Use it to calculate the force exerted by each attached pipe. Then add those forces to determine the total resultant force (F) exerted by all the piping.

Once you have calculated the resultant force, compare it to the following relationship:

$$F \leq 0.1 \times \text{System Accuracy (in \%)} \times \text{Live Load (pounds)}$$

where:

For 0.1% System Accuracy, $F \leq$ 1% of Live Load

For 0.25% System Accuracy, $F \leq$ 2.5% of Live Load

For 0.50% System Accuracy, $F \leq$ 5% of Live Load

For 1.0% System Accuracy, $F \leq$ 10% of Live Load

If the resultant force satisfies this relationship, then the force exerted by the piping is small enough that you can compensate for it during calibration.

 © 1999 Mettler-Toledo, Inc. (www.mt.com)

Example Calculation

⚠ CAUTION

CALCULATIONS ARE PROVIDED AS GUIDELINES ONLY. THEY SHOULD NOT REPLACE A STRUCTURAL ENGINEERING EVALUATION OF THE APPLICATION BY A REGISTERED PROFESSIONAL ENGINEER WHO IS FAMILIAR WITH LOCAL BUILDING CODES.

Suppose a customer requires a tank scale with a system accuracy of 0.1% of the applied load. One pipe will be connected to the tank. To meet the system accuracy requirement, the vertical force exerted by the pipe (F_P) must be equal to or less than 1% times the live load of the system. For this application, assume that the live (net) load equals 25,000 lb.

Use the resultant force formula to determine the maximum pipe force that you can compensate for during calibration:

$$F_p \pounds 0.1 \times 0.1 \times 25{,}000 \text{ lb}$$

F_P cannot be greater than 250 lb maximum pipe force.

Use the pipe force equation to calculate the actual force exerted by a pipe with the following characteristics:

D = 4 inches (Outside diameter of pipe)

d = 3.75 inches (Inside diameter of pipe)

Δh = 0.09 inch (Total deflection of pipe at the vessel)

$E = 29 \times 10^6$ (Young's modulus)

L = 60 inches (Length of pipe from the vessel to the first support point)

$$F_P = \frac{0.59 \times (256 - 197.75) \times 0.09 \times 29{,}000{,}000}{216{,}000} = 415.27 \text{ lb}$$

Since a pipe force of 415.27 lb is greater than 250 lb, it would not satisfy the requirement for a 0.1% accuracy system. One solution is to increase the length of the pipe from 60 inches to 80 inches. When you recalculate the pipe force for a length of 80 inches, you get F_P = 175.2 lb, which is well below the maximum of 250 lb.

Piping Installation

This section shows ways to install piping in order to avoid deflection problems.

The greater the distance between the tank and the first pipe support, the more flexible the piping connection will be (see Figure 5-21a). Use a section of flexible hose so that the pipe does not exert unwanted forces when the tank deflects (Figure 5-21b).

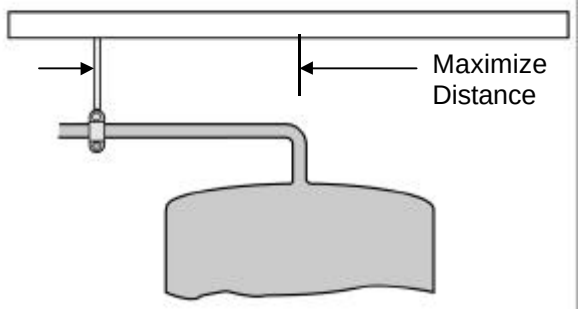


Figure 5-21a: Distance Between Tank and Pipe Support

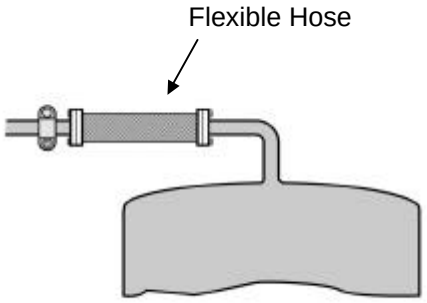


Figure 5-21b: Piping with Length of Flexible Hose

A 90-degree bend in a horizontal run of pipe will make the piping more flexible (see Figure 5-22).

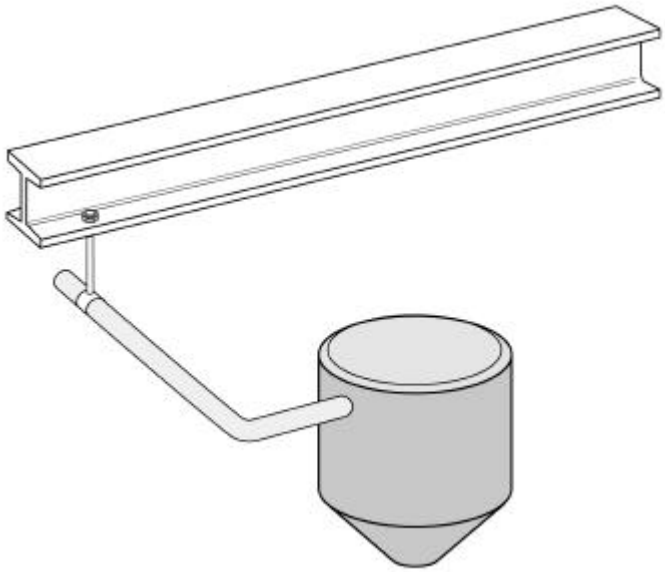


Figure 5-22: Horizontal Piping with 90-Degree Bend

 © 1999 Mettler-Toledo, Inc. (www.mt.com)

When a single discharge pipe is used by adjacent tanks (see Figure 5-23a), the weight of material being discharged from one tank can exert a downward force on the other tank. Instead, design the system so that the discharge piping from each tank is supported independently and does not interact with the other tank (see Figure 5-23b).

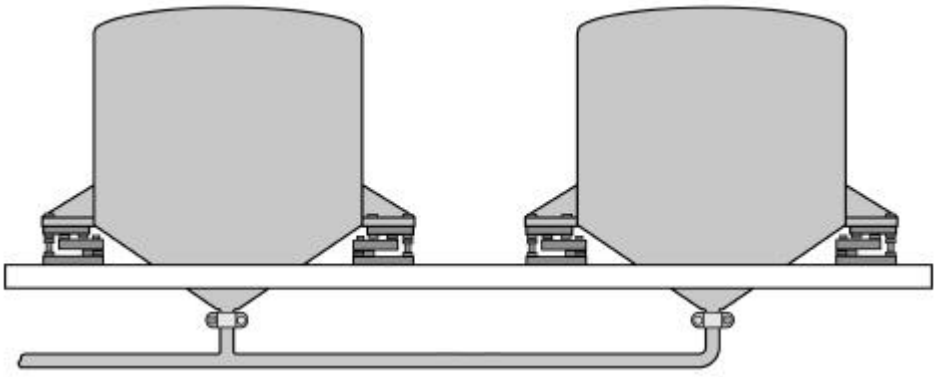


Figure 5-23a: Tanks with Single Discharge Pipe

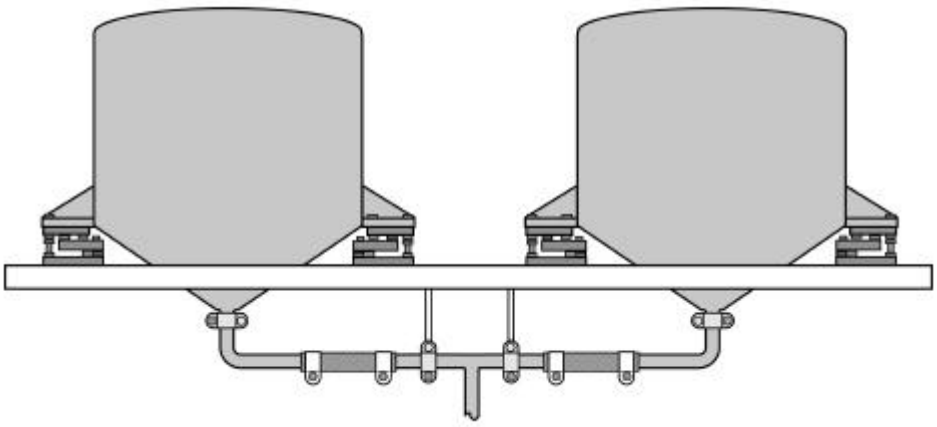


Figure 5-23b: Recommended Design for Single Discharge Pipe

Do not attach piping to supports for a mezzanine, upper floor, or other structures that deflect separately from the tank (see Figure 5-24a). Instead, attach piping to the tank's support structure so that the piping moves along with the tank (see Figure 5-24b).

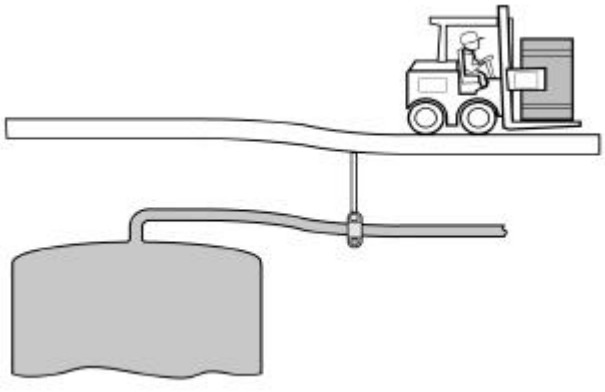


Figure 5-24a: Piping Supported by Upper Floor

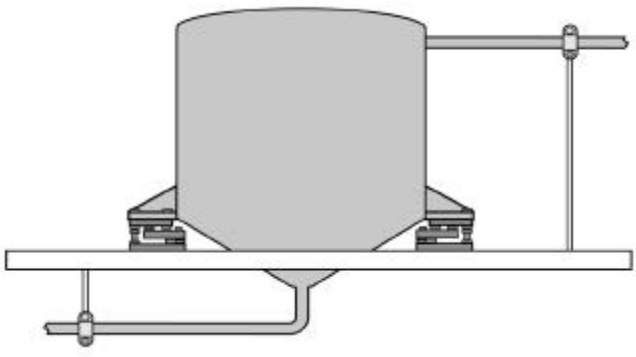


Figure 5-24b: Piping Attached to Tank's Support Structure

When possible, avoid rigid connections between piping and tanks. Note the clearance between the tank and inlet/outlet piping in Figure 5-25. A flexible boot is used to seal each connection.

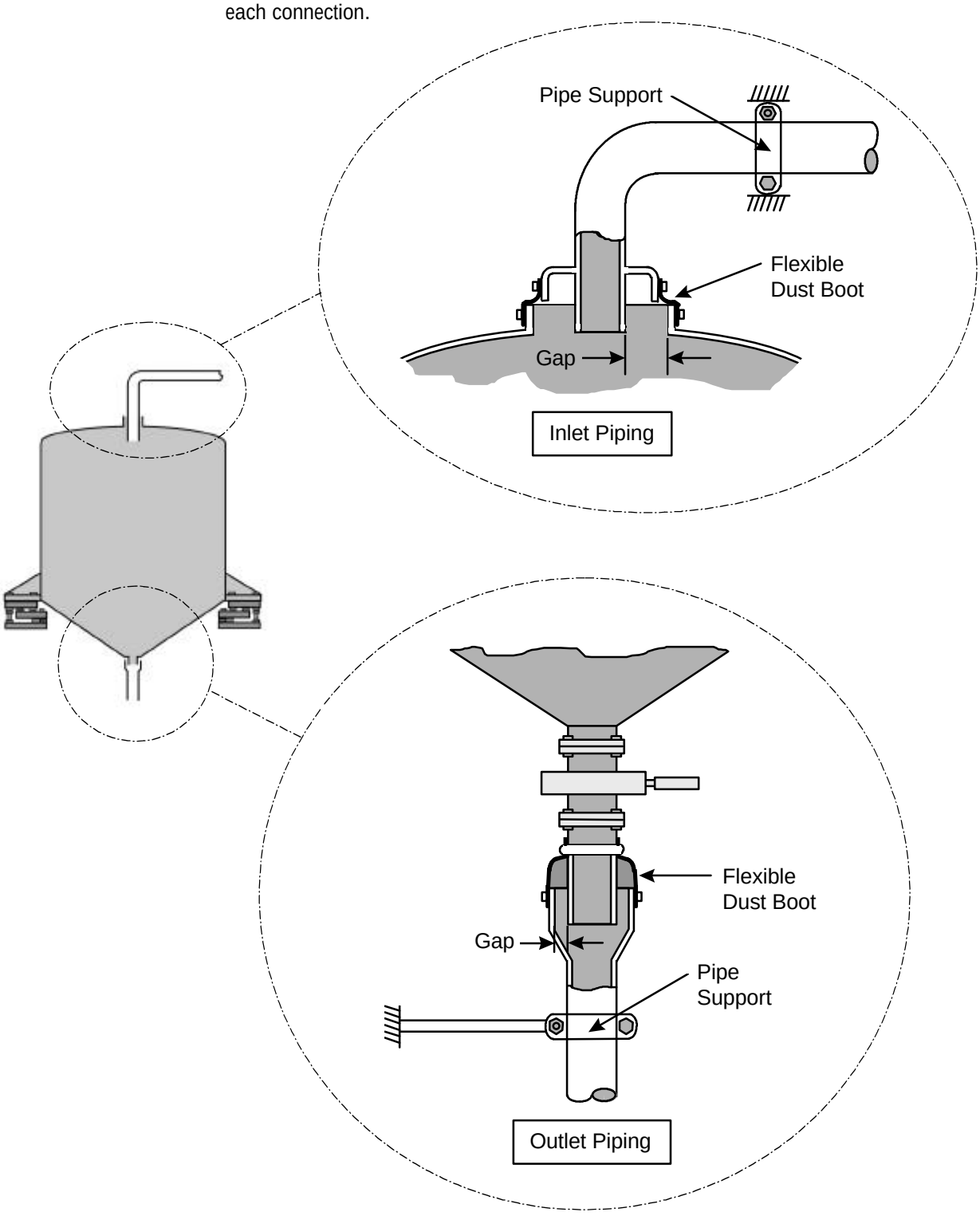


Figure 5-25: Recommended Flexible Connections Between Tank and Piping

 © 1999 Mettler-Toledo, Inc. (www.mt.com)