Steel tanks: Basics of foundation design and material selection

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This article covers the basics of specifying a large steel tank or silo for storing your dry bulk materials and provides information about standards that can help you in this task. Sections focus on foundation design and how to select steel, bolts, and sealants for the tank.

Steel tanks for storing dry bulk materials are available in bolted, field-welded, and shop-welded designs. Which is best for your application depends on several factors, including the storage capacity the tank must provide, what interior and exterior coatings your tank may require, and the tank design’s shipping and field labor costs.

All steel tanks are constructed of individual steel panels. The bolted tank and field-welded tank are constructed on your site, while a shop-welded tank is constructed in the tank manufacturer’s facility and then shipped to your site for installation.

- The bolted tank typically has a small to large storage capacity, with a diameter up to 200 feet (its height depends on the steel thickness’s capabilities). The tank has a high-quality baked-on coating and modular construction that reduces its shipping costs, but it requires field labor for bolting the panels together onsite.

- The field-welded tank provides large capacities and is available in the same dimensions as a bolted tank. Constructing this tank involves labor and installation costs for cranes and specialized installation rigging, field welding by skilled welders, field blasting for removing rust and millscale on the tank’s steel surfaces and to prepare the surface for primer and paint, and field-applied coatings that must be air-dried. Like the bolted tank, the field-welded tank has modular construction that reduces its shipping costs.

- The shop-welded tank has a small to medium storage capacity and a diameter limited to 15 feet with a height usually under 100 feet because it’s shipped to the site by truck. This tank has a high-quality factory-applied coating and requires field labor only for installing tank accessories (such as dust collectors, stairways, ladders, guardrails, piping connections, and level controls), but requires specialized truck trailers for shipping and cranes for installing the structure onsite.

Specifying the right steel tank for your needs requires working closely with the tank manufacturer or construction contractor for your project. This expert can help you design the tank’s foundation and choose the right construction materials — two factors critical to the tank’s long-term success. The following information can help you get started.

Designing the foundation

A long-lasting, properly operating storage tank must have a solid foundation. The first step in designing the foundation is contracting an experienced geotechnical company to perform...
Steel sheets and plates for bolted tank panels are commonly made of ASTM A36, A283, A572, A656, or A1011 steel, as listed in the standards ANSI/American Petroleum Institute (API) Spec 12B: Specification for Bolted Tanks for Storage of Production Liquids and ANSI/AWWA D103-09: AWWA Standard for Factory-Coated Bolted Steel Tanks for Water Storage.¹

For a welded steel tank, a critical requirement for steel panels, besides strength, is weldability. Weldability indicates how heat affects the steel’s structure, how easy it is for a welder to create good welds with the steel, and how strong the weld is relative to the base steel’s strength. Mild carbon steel sheets and plates are typically used for panels in welded tanks because of their high weldability. Examples include ASTM A36, A131, A283, A285, A516, A537, A573, A622, A633, A635, A662, A678, A737, A841, and A1011 steels, as listed in the standards ANSI/API 12D Specification for Field Welded Tanks for Storage of Production Liquids, ANSI/API Spec 12F: Specification for Shop Welded Tanks for Storage of Production Liquids, API 620: Standard for Design and Construction of Large, Welded, Low-Pressure Storage Tanks, API 650: Standard for Welded Steel Tanks for Oil Storage, ANSI/AWWAD100-11: AWWA Standard for Welded Carbon Steel Tanks for Water Storage, and Underwriters Laboratories (UL) 142: Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids.² Steels with higher carbon content can require preheating and slow cooling or other special procedures to make them suitable for welding, and these procedures can cause cracking that reduces the steel’s strength.

Before writing your tank specification, consult the tank manufacturer for advice about which steel is best for your tank type, your application, and the applicable standards.

Choosing bolts and sealants

Bolts and sealants are used to assemble the steel panels on bolted tanks. Two common horizontal bolted joints — flanged and lap — for steel panels are shown in Figure 1. Bolts and sealants can also be used on manways, ladders, piping connections, and similar accessories on both bolted and welded tanks.

Bolts. Bolted connections on your steel tank are subject to high levels of shear, tension, and torsional stress. If the bolts aren’t properly selected, these stresses can cause the bolts to fail, as shown in Figure 2. You must carefully select not only the bolt type, material, size, and strength, but the bolt quantity, spacing, and bolting pattern to resist these stresses and provide long-lasting connections. The tank manufacturer can help you make these decisions based on your application’s requirements.

Which bolt material (such as steel or steel alloy type) and strength are best for your tank depends on the material it stores. When exposed to certain stored materials and vapors in the tank, some bolt materials can undergo changes such as stress crack corrosion and embrittlement (in which the bolt material loses ductility). For instance, high-
strength steel bolts and bolts made from high-strength steel alloys can become embrittled when exposed to moist hydrogen sulfide and other sulfidic environments. And high-strength steel alloy Society of Automotive Engineers (SAE International) J429 grade 8, SAE J995 grade 8, and ASTM A490 bolts can’t be galvanized by the hot-dip method (that is, dipping them into molten zinc) because this process can also embrittle them.3

Zinc-plated or galvanized bolts are most commonly used in steel tanks. If the bolt heads will be exposed to a corrosive stored material (such as some chemicals, minerals, acidic wood products, or nut shells) or can contaminate the stored material (such as a food product stored in an FDA- or NSF-compliant tank), you can select bolts with heads that are encapsulated with special polymers that resist corrosion and provide a tight seal with the tank’s steel surface.4

Remaining pliable over the tank’s life ensures that the gasket or adhesive sealant will provide a tight seal and resist expansion and contraction.

**Sealants.** Choosing the right sealant for the bolted steel panel joints on your bolted tank (and in some bolted tanks, for the area between the bolt head and the steel panel surface) and for your bolted or welded tank’s bolted accessories is important to the tank’s long-term performance. These sealants may take the form of semirigid gaskets or adhesive sealants:

- A semirigid gasket can be made of neoprene, nitrile, silicone, or other similar material and has firm outer edges around a pliable inner surface.
- An adhesive sealant is typically a single-component material in a tube that’s dispensed as a bead using a tool similar to a caulking gun; the sealant is then air-cured so that its outer edges become firm while its inner area remains pliable.

Remaining pliable over the tank’s life ensures that the gas-

**Figure 1**

**Common bolted joints for steel panels in bolted-steel tanks**

- Flanged joint
- Lap joint

**Figure 2**

**Bolt failure due to stresses**

- Failure from shear stress
- Failure from tension stress
- Failure from torsional stress

**This bolted-steel embedded sidewall, shown here prior to pouring the concrete floor, forms part of the foundation that will support a bolted-steel tank.**
A ket or adhesive sealant will provide a tight seal and resist expansion and contraction.

To select a sealant compatible with your tank application, determine how well the sealant meets these three criteria:

1. The sealant retains its properties and doesn’t degrade over time.
2. The sealant’s performance isn’t affected by its environment and operating conditions.
3. The sealant is compatible with your stored material.

For instance, to handle bolted connections in a tank operating at high temperature, you can choose an adhesive sealant made of silicone or heat-resistant urethane. For a tank storing a material containing oil, an adhesive sealant made of oil-resistant silicone would be suitable.

The path to long-term tank success

Partnering with your tank manufacturer or construction contractor as you specify the tank, its foundation design, and its construction materials is key to the project’s success. These experts have years of real-world experience with tank design and construction, so rely on their knowledge of tank specifications and sound engineering judgment and practices to help you specify a steel tank that can reliably store and discharge your dry bulk material for decades to come.

References


For further reading

You can find more information on dry bulk storage tanks and silos in articles listed under “Storage” in Powder and Bulk Engineering’s comprehensive article index (in the December 2011 issue and at PBE’s website, www.powderbulk.com). You can also purchase copies of past PBE articles at www.powderbulk.com.

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