Preventing Tank Flotation

Excerpt from Technology of Underground Liquid Storage Systems, Independent Study Course

Independent Study Course
The information in this article is based on two simple principles: (1) If you take a tightly capped empty jar and hold it under water, the jar will try to force its way to the surface; and (2) a large jar will exert progressively more upward pressure than a small jar.

Highlights

When tanks are installed in areas with high water tables, or in areas subject to flooding, the installation must include restraints that will prevent tanks from floating out of the ground. In this article, you will learn more about:

- Alternative preventive methods
- Basis for selecting each method
- Installation procedures
- Preventing tank damage

This article is drawn from the Technology of Underground Liquid Storage Systems, Independent Study Course (ISC), a 20-lesson course. The course material has been developed for the University of Wisconsin-Madison's live training courses, and is based on nationally recognized codes and standards.

If 70 percent of a tank's storage capacity falls below the flood level, anchor the tank.

An empty, air tight bottle will float on water. If forced under water, it will rise to the surface when the downward pressure is released. An underground storage tank submerged in a flooded excavation reacts the same way, except it contains a greater volume of air and exerts much more up-ward force. Even tanks partially filled with product may float. In fact, some improperly installed tanks have broken through concrete paving after a period of heavy rain.

If the water table consistently remains below the bottom of the tank excavation and the region is not subject to periodic flooding, supplemental restraints are unnecessary. Here is the conventional wisdom: If 70 percent of a tank's storage capacity falls below the flood level, anchor the tank.

At the same time, if the water table periodically rises to a level above the bottom of the excavation or if the region is subject to periodic heavy rains, fire codes require that flotation be prevented.

In addition to areas with a high water table and regions prone to flooding, system designers favor supplemental holddown in the following conditions:

• During Construction. For a short period of time during an installation, the tank is held down only by the weight of the tank, ballast and partial backfill. This weight alone may be insufficient in impervious soils if the volume of water entering the excavation exceeds pumping capacity.
• For Inspection. Occasionally, the owner or engineer may need to establish stopping points during construction for inspections to be made. This interruption in the normal construction work increases vulnerability of tanks to flotation. Additional precautions may be advisable if work must be left to a possibly unqualified “low” bidder.
• In Unstable Soils. Supplemental holddown may be required if there is concern that movement of the backfill or bedding is not controllable through the use of filter fabric. Additional excavation and construction of a suitable base for the tank or use of an aboveground tank should be seri-ously considered.

Prudent system designers oppose any indiscriminate mandatory supplemental holddown requirements. They consider them unnecessary if pumps can be used to keep the water level down during construction and if the tanks will be secure when the installation is completed. Such methods are costly, provide no benefit and the additional work of constructing restraints in the excavation increases the workers’ exposure to safety risks.

Buoyancy

Buoyant force is the upward force that an object displays to float or rise in a liquid. The rule of thumb is:

Buoyancy to be offset is equal to the weight of the volume of water that the tank displaces or can hold, less the weight of the tank and attached equipment.

The weight of backfill material and paving over the tank are the principal factors offsetting buoyancy. The weight of the empty tank and attached equipment, fric-tion between the tank walls and backfill, and voids in backfill over the tank due to manway openings have a lesser effect on buoyancy. Removing water from the excavation during placement, backfilling and ballasting is essential regardless of tank diameter or capacity. Increasing the tank’s burial depth provides the greatest advantage to countering flotation. The use of deadmen is the second most effective method.

The most critical factor in determining buoyant force is tank volume. The greater the capacity of the tank, the greater the volume. (The effects of friction are not considered and add to the safety factor.)

Other determining factors include:

• Weight of product stored
• Submerged weight of the tank and associated equipment
• Submerged weight of backfill material and paving
• Height of water around the tank

Submerged weights are used in the calculations, since a worstcase scenario presumes that water will be up to the height of the finished paving, with all components submerged. To determine the submerged weight of a material, deduct the weight of an equal volume of water from the weight of the material.

Planning

No two UST installation sites are the same. Anchorage (holddown) requirements are determined by the sitespecific conditions of each installation. **Figure 1** indicates the improvement in the factor of safety for 8 or 6 foot diameter tanks when you increase burial depth, add deadmen or add a holddown slab vs. a tank installed with a 3 foot burial depth: Following are some general guidelines to keep in mind.

• Plan for a worst case scenario.
• Check for local code requirements.
• Consider the bathtub effect.
• Anchor 12 foot diameter tanks if the water level could be expected to reach the bottom of the tank.
• Keep in mind that the size of the excavation may need adjustment.

The worst case scenario occurs when the tank must be restrained while it contains little or no product, and the water level in the excavation reaches finished grade. If soil conditions or the depth of the water table are unknown at the time of installation, or if heavy rains are likely to occur during construction, contingency plans should be made for adding supplemental restraints as well as for having pumps, hoses, straps, cables and other anchoring materials readily available.

Figure 1

Other Major Considerations

Fire codes require that horizontal USTs and ASTs be anchored if more than 70 percent of the tank's storage capacity would be submerged at the established flood stage. Tanks may be anchored to a foundation of concrete or steel and concrete of sufficient weight. This will prevent movement when the tanks are filled with flammable or combustible liquid and submerged by flood waters or when the tanks are adequately secured from floating by other means. Absent any other requirements, local authorities define the established flood stage.

Bathtub effect is not uncommon in areas with impervious soils such as clay. In such a situation, infiltration of surface water into the tank excavation may cause the UST to float. That is, the tank excavation holds water the way a bathtub holds water. This is called the bathtub effect. Localized flooding can occur while the surround-ing area remains unflooded.

Larger diameter tanks are more susceptible to flotation. Some manufacturers of 12 foot diameter tanks have, in the past, required that they be anchored. Most manufacturers continue to recommend it.

Design plans for the UST installation should include deepening and enlarging the excavation to permit

proper installation of restraining devices. Deadmen, for instance, must be located outside of the profile of the tanks to achieve maximum benefit. A wider excavation may be required. Similarly, if a full bottom tank holddown pad is required, the depth of the excavation will need to be increased.

The openings of tank vents and other non-liquid-tight tank fittings should terminate and be made liquid-tight to above the maximum flood stage water level.

Selection

When additional anchorage is deemed necessary, an approved method must be selected. The most common alternatives are:

- Increasing burial depth
- Providing deadmen anchors
- Incorporating a thicker paving slab
- Using a full bottom holddown pad

Increased burial depth and a thicker paving provide protec-tion only after the installation is completed. While construction is underway, tanks must be secured against movement without the benefit of the weight of backfill and paving. The best way to do this is to keep the water level in the excavation below the bottom of the tanks.

In severe conditions, this might require continuous pumping or well-pointing. Well-pointing involves dewatering the tank area through the use of large pumps connected to a series of perimeter well-points. Disposal of pumped water will take some advance planning and, if the water is contaminated, disposal permits.

Tank Burial Depth

Increasing tank burial depth increases the weight of the backfill overburden. This method is less costly than the other methods, and safer because workers might not be required to enter the excavation.

In general, normal backfill and paving over the tank will provide adequate restraint if the burial depth is at least 60 percent of the tank diameter.
For example, 60 percent of an 8-foot diameter tank is 4 feet by 9 inches. Therefore, the top of the tank should be at least 4 feet 9 inches below finished grade level.
Adding one foot of additional burial depth to a 10,000 gallon 8-foot diameter tank provides an additional 13,392 pounds to counter flotation.

A concrete paving slab provides the tank with mechanical protection by spreading any live load from vehicular traffic and impeding the flow of water into the excavation. The slab also adds to the weight countering flotation; concrete is 46 percent heavier than the backfill it replaces (87.6 pft^3 versus 60 pft^3). Each inch of reinforced concrete above the tank can be con-sidered equal to 2 inches of compacted backfill.

As a general rule, design the paving slab to be as wide as the diameter of the tank, plus 4 feet, and as long as the tank, plus 4 feet. The slab should extend 2 feet beyond the tank in each direction (see **Figure 2**). It is recommended that the corners of pads be mitered at 45 degree angles to prevent cracking and breaking off during use.

Figure 2

Deadmen Anchors

When circumstances are not conducive to increasing burial depth, and if supplemental restraint is needed while construction is in progress, deadmen anchors are preferred (**see Figure 3**). They are made of reinforced concrete (generally between 8 and 12 inches thick and 18 to 36 inches wide), either precast on-site or furnished by the tank manufacturer and delivered to the jobsite with the tank.

Deadmen provide protection during and after construction. This is a popular method because deadmen are effective and reduce the amount of work required in the excavation. The combination of deadmen anchors and the temporary lowering of the water level in the excavation by pumping and deadmen provide sufficient protection, even in severe cases.

Figure 3

Bottom holddown pad

A bottom holddown pad is usually 8 inches of reinforced concrete extending at least 18 inches beyond the tank sides and 1 foot beyond each end. The pad provides a firm foundation for the tank and helps to offset buoyancy as well. (See **Figure 4**) Calculate the thickness of the pad, as well as the number and size of anchors and reinforcement for each installation to determine the offsetting value.

Figure 4

Holddown Hardware

There are three basic requirements for hardware (straps, anchors and turnbuckles) used to secure the tanks to deadmen or bottom slabs:

- They must be strong enough to do the job.
- They must not damage the tank structure or coating.
- Excessive corrosion must be prevented.

Straps may be of steel or nonconductive material with sufficient integral strength to restrain an empty tank, fully submerged in water. Steel straps are generally furnished by steel tank manufacturers and should be sep-arated from the tank surface with a dielectric material.

A preferred way to protect the coating of steel tanks is by wrapping the steel straps in an insulating channel provided with the straps by the tank manufacturer. Fiberglass tanks have straps placed at specific locations to line up between the structural ribs. The number, size and placement of straps should be determined by the manufacturer. Strap insulating material must be nonconductive, compatible with the materials being stored and suitable for use underground.

Turnbuckles or other screwtype devices should be used to allow for adjusting strap tension (see

Figure 5). While excessive tightening can result in damage to the tank, loose straps can allow tanks or straps to move from designated positions. Neither condition is acceptable.

Protect hardware from corrosion by coating the surfaces with a thick coating of dielectric material. Anodes are not generally used because of the difficulty in defining the structure to be protected. If the anchor bolts are tied into the reinforcing steel of the tank pad or deadmen, it is very difficult to calculate of the size, number and type of anodes to be effective.

Provide sufficiently thick material to allow for some corrosion without failing. The use of a corrosion allowance in place of anodes is recognized by Underwriters Laboratories in exempting steel tanks from internal cathodic protection.

Figure 5

Construction

Following is some advice from experienced installers:

- Reduce the water level in an excavation to the lowest practical level during construction.
- Keep the ballast level in the tank below the level of water or level of backfill.
- Use lifting equipment to stabilize the tank during plac-ing of ballast and backfilling.
- Do not use cradles, beams, sandbags, or timbers in the excavation.
- Be careful when designing or constructing bottom holddown pads.
- Install hardware carefully.

Determining water infiltration—If the extent of ground water or surface water infiltration cannot be accurately determined before bidding, there is an effective way to delineate between normal and high water conditions. Require the installation contractor to handle normal water to the extent possible with two 2-inch pumps. Beyond that, a high water condition requires additional pumping or well-pointing.

Preventing tank damage

Fiberglass tanks rely on the backfill for part of their structural integrity. They can be damaged if filled with product above the level of backfill surrounding the tank. Following the manufacturers' instructions for all installations is an important and reasonable precaution.

In a wet hole, it may be necessary to use lifting equipment to keep the tank from rolling while it is filled with product and backfilled. If so, leave sufficient slack in the lifting cable to allow the tank to roll slightly. Putting severe strain on the cable at this time may cause structural damage to the tank.

Blocking tanks in place can cause serious structural or corrosion damage to installed tanks if the blocks are accidentally left behind. These devices have the effect of creating stress points on the tank surface which can damage the coating or structure.

Never place a tank directly on a concrete bottom holddown pad; at least 12 inches of backfill bedding material must separate the tank and concrete. Also, a bottom holddown pad should never be shorter

than the full length of the tank; otherwise, uneven stresses can develop, leading to structural failure.

Securing tank straps

Ensure that the straps and tank surface are free of debris or burrs that might damage the insulation or tank coating. Coat metallic anchoring hardware, including bolts, turnbuckles, straps, clamps, wire rope and connectors, with dielectric material. Distribute insulating material evenly and test to ensure electrical isolation after installation.

Firmly secure tank straps to anchor bolts with threaded connections, or to cables and clamps. Snug down straps with the turnbuckles before backfilling. Take care to prevent damage from over tightening.

Use of wire ropes or round bars instead of straps is not acceptable. Wire rope can be used to secure straps to the anchor points. If wire rope is used, clamps should be secured from one side to avoid excessively handling the rope.

In the past, roofing felt and expansion joint material have commonly been used between steel tanks and straps. This is unacceptable because these materials con-duct electricity and are not acceptable as insulating material.