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Solving Cold Weather Problems for Storage Tanks

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A frozen water storage tank is worse than no tank at all. How does a storage tank freeze, and what happens when it does? Consider this story about a ground storage tank in North Carolina.

The storage tank was located at a high elevation in an area with an average coldest-day temperature of +5°F (–15°C).

The tank was the second one on the system. Its water level was controlled by an altitude valve in an unheated and uninsulated concrete pit. The troubles began when an uninsulated ½-in. (12-mm) control pipe apparently froze, causing the altitude valve not to sense the full tank.

The tank overflowed, and ice soon plugged the overflow pipe. The roof hatch and vent also froze over—either from freezing rain or the overflowing water.

The tank apparently froze solid, pushing the bottom down. Anchor bolts had been specified on this contract, although they were not needed for wind loads. Some of the anchor bolts pulled out of the concrete. Other anchor bolts stayed in the concrete but pulled the anchor bolt chairs out of the steel tank wall, ripping holes in the steel.

When the tank thawed enough for the water to drain from the tank, a vacuum was created. The vacuum was so strong it sucked the roof in. (Remember, the vent and hatch were frozen over.)

This was about as classic a failure as could occur on any one tank. The tank was new, not yet accepted by the owner, but in service on the system. This created untold questions of liability among the owner, engineer, contractor, and subcontractor.

What Makes Tanks Freeze?

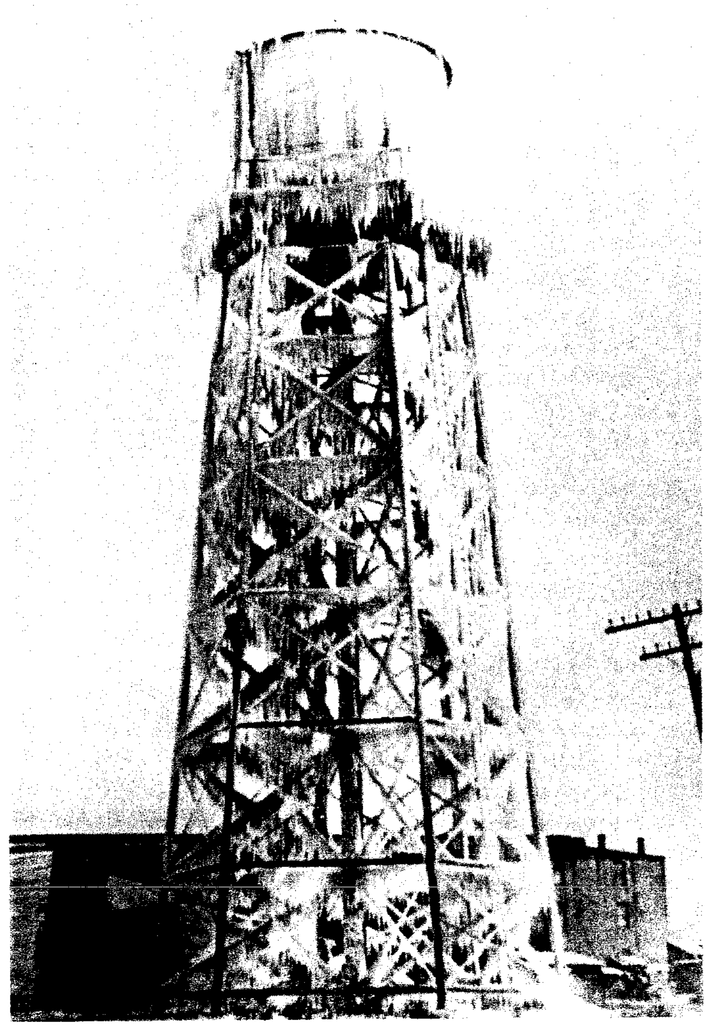
What makes storage tanks freeze? Basically, there are three causes: static water conditions (lack of sufficient water turnover), tank overflow, and improper design of the structure. Under each cause falls a number of contributing factors, for example:

- Static conditions occur when tanks are reserved for fire protection or when a tank is too large for the present system.
- Overflows may be caused by leaky valves or frozen controls for pumps or altitude valves.
- Troublesome design elements may include vent design or insufficiently insulated pipe or riser.

With such a definitive list, you might think that preventing cold weather problems with tanks is an exact science. It certainly is not!

How Cold Is Too Cold?

The most accurate and useful figures for estimating how cold an area is likely to get are the lowest one day mean temperatures (LODMT) recorded by the US Weather Bureau.



This photograph was taken on Feb. 1, 1913, in Batesville, Ind. *Courtesy Tank Industry Consult·nts.*

Turnover in Tank Can Prevent Freezing

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These figures tell you how much cold you can expect in an average year.

In addition, the National Bureau of Fire Underwriters publishes tables giving the heat loss per hour from various types of tanks. A 250,000-gal (1-ML) elevated tank located in a –10°F (–23°C) area loses 1 million Btu/h (293 kJ/s) in a 12-mph (19-km/h) wind. Move the tank to a –40°F (–40°C) location, such as International Falls, Minn., and the heat loss almost doubles.

Of course, weather follows no rules, and a community may occasionally get much colder than the averages recorded by the weather bureau. For example, the winter of 1976–77 rewrote a lot of history on frozen tanks in areas normally immune to such problems.

As a general rule of thumb, based on experience, areas warmer than –5°F (–21°C) will not experience cold weather problems. But, of course, there are exceptions. These include:

- elevated tanks with less than 36 in. (1 m) uninsulated risers;
- tanks with unheated and uninsulated appendages with no flow, for example, a drain valve at the end of a nipple;
- overflowing problems due to frozen or otherwise malfunctioning controls for valves or pumps;
- tanks with static water conditions; and
- tanks with inadequate vents or overflows.

Tanks with these problems may freeze even in areas where the coldest-day average is above –5°F (–21°C).

Cold Weather Operations

A number of steps can be taken to prevent freezing. Some of these steps must be taken as part of design; others are a matter of operations.

Achieve water turnover. With proper management and piping, the heat needed to prevent freezing can be added to the tank with fresh well water. If 222,000 gal (840 kL) of 45°F (7°C) water is pumped in one day through a 25,000-gal (950-kL) storage tank, the heat added would replace the heat that is lost to a 12-mph (19-km/h) wind in –10°F (–23°C) weather.

Although replacing most of the water in a tank with warmer water every day is possible, it is not the way a tank usually is operated. Water storage tanks, particularly elevated tanks and standpipes, usually float on the system—that is, water may enter the distribution system without passing through the storage tank.

Because of this, a tank may serve a system that actually uses much more water than the tank can hold—but the tank receives only a small percent of new or fresh water in it.

Forcing circulation through tank. If the tank is located near a pumping facility, the tank can be piped so that new, warmer water enters the tank through one pipe and exits through another pipe.

In order to force the warm water to circulate, the new water should enter the tank above the capacity midpoint. Such piping, however, violates a rule of good design practice. *First, it increases pumping power costs.* Second, the pipe that extends inside the tank could be broken off by ice cakes if improper pumping allows ice to form.

Pumping management. In a small community or in sections of a large water system, pumping can be used to achieve turnover. During the day, pumps are used only to maintain the minimum emergency-reserve level. At night, the tank is filled. This not only ensures flow during periods of low demand, but it adds heat at night, when heat loss is at its peak.

This system works best for automated systems, where clocks can be integrated with the pump controller.

In large systems, pumps are usually sequenced cumulatively to meet demand. Consider changing winter operating procedures: Let system pressure drop a little more than usual, then switch on several pumps at nearly the same time. This will cause greater fluctuations in the water levels of storage tanks.

Lowering high-water level. If it is possible to keep less water in the tank during the winter months (while maintaining enough reserve for power outages and fire flow), consider lowering the winter high water level about 10 ft (3 m), or into the vertical portion of a curved-side tank. This minimizes the probability of ice forming on the upper curved portion or roof support structure.

Keep an eye on altitude valves. Altitude valves are often used in systems where the tank's high-water level is lower than the pressure gradient of the system. Even some small, one-tank systems have been designed with an altitude valve on the tank inlet–outlet line.

Altitude valves may malfunction even in good weather. Freezing weather brings special problems. For example, frozen pressure-sensing lines give the altitude valve false signals. Usually, this causes the valve to stay open, and the tank overflows. However, in some situations the valve may stick shut, keeping water in the tank static.

Check ground cover on connecting pipes. A common cause of tank freeze-ups is lack of protection for the pipe leading to the tank. Sometimes soil conditions make it impossible to install the tank foundation deep enough to provide adequate frost cover.

In this case, some kind of fill should be brought in to cover or insulate the pipe, or some other means should be used to insulate the pipe.

Some tower-type elevated tanks have the riser foundation built higher than the column foundations. The site should be graded higher in the center, to keep the inlet–outlet piping from being exposed to the atmosphere between the concrete tunnel roof and the earth.

Compacting fill. If the earth over the connecting piping is not compacted properly, it will settle during the first few years of operation. The lack of adequate cover, plus moisture saturation of the depression, creates an area prone to freezing.

Supervising backfill. The base of the tank is usually where the responsibilities of several contractors meet, and it may become a no-man's land. Unless properly supervised and inspected, the piping may not get backfilled at all before the first winter of operation.

When the Tank Freezes

When a tank freezes, the following may result:

- inside overflow or other piping breaks;

Thawing Tank, Repairing Damage Requires Special Care

- ladders or other attachments to the container are pulled out by ice, making a hole at the point of attachment;
- ice pressure expands riveted or bolted seams, or breaks plates, welds, bolts, or rivets;
- leaks due to corrosion become apparent.

Overflow through overflow pipes. When storage tanks overflow in freezing weather, all sorts of problems can develop. An overflow to grade often freezes solid, especially when the overflow is just a trickle or when there are plugged screens or stuck flap valves on the discharge.

If water continues to be pumped into the tank after the overflow pipe is frozen solid, it may overflow for a while through the roof hatch, then the vent. Then the tank will freeze solid; eventually, it will build up pressure and burst.

Overflow through the roof hatch or vent. While overflowing through the hatch and vent, the water will form a large icicle, weighing tons, on the tank exterior. This places a large eccentric load on the structure. In the case of water towers, this load usually exceeds the design stresses on the structure. The icicle is usually on the opposite side of the tank from the prevailing wind, causing additive loadings.

Even if the structure is not damaged by the ice load, it is frequently damaged by falling ice as it thaws or breaks off. Icicles and resulting damage have caused water towers to fall down. A tank with a stub overflow (one extending only a few feet from the shell of the tank) can form icicles on the structure by merely overflowing.

Icicles form. Once ice forms on the tank exterior, it creates a hazard for all people and objects below. If the ice appears likely to cause structural failure, a distance of greater than the height of the tank should be roped off.

If the danger appears to be falling ice, an area at least 20 ft (6.1 m) larger in radius than the tank should be roped off. If in doubt about the stability of the structure, take all precautions and call a structural expert to analyze the situation.

Thawing a Frozen Tank

Despite all efforts, a tank may still freeze. When this happens, there are two ways of thawing it:

- thaw the tank artificially or
- wait for warm weather.

When you suspect that the tank is frozen, do not attempt to drain the tank. This can cause damage in three ways:

- the ice may fall inside the tank, damaging the tank or piping;
- the vent may be plugged, causing the roof to collapse due to the vacuum formed when you try to drain the tank; or
- the ice may thaw in the tank on only one side (the side facing the sun). This will allow water to drain off that side of the tank, producing an eccentric load on the structure. In the case of a single-pedestal tank, this may bend the support cylinder.

If your tank is frozen and you are in doubt about what to do, it is good practice to get the advice of a tank company or structural consultant.

Keep pipes frozen. If ruptures or leaks are apparent in the inlet or riser piping, it is usually best to let nature take its course, or even keep that piping frozen. This will keep water in the tank while things are still frozen overhead.

Thawing pipes. If piping is frozen where it enters the tank or riser pipe at ground level, and it is all right to let the water flow again, the pipe may be thawed.

One way to do this is to put up a tarpaulin or polyethylene film tent around the base and use a gas- or oil-fired portable heater to heat the area. If the tank is a single-pedestal or other similar design with a large dry riser, heat may be applied in that portion of the tank.

Thawing tanks. A water system may try to thaw the tank with its own equipment, but contractors are often hired to do the job.

A common method is to lift a ¾-in. (19-mm) heavy-duty hose from the ground up over the top of the tank. The end of the hose ends with a ½-in. (12.7-mm) pipe about 10 ft (3 m) long. This is called the probe.

This pipe is dropped through the tank vent or manhole that is over the inlet or riser pipe. It must be kept slightly off the ice to keep it from sticking to it. Warm water from a fire department tank truck is pumped through the hose, parting the ice as the probe drops down.

The water must keep flowing at all times. Stopping in the middle of the process may mean leaving the equipment in the tank for the rest of the winter.

When the fire truck is empty, it must be refilled from the utility mains. The refill water will not be as warm as the water that was taken from the tank truck, which has been sitting in the heated fire station.

Some systems use a steam generator that is attached to the same type of probe, but the warm water method seems to work best. It also creates fewer safety hazards.

It may be difficult to thread the probe into the riser pipe. Before you start, review a tank drawing or a recent inspection report to find out where piping is positioned.

Thawing a tank artificially is expensive and dangerous. Often, warm weather will return the day after the crew has thawed the tank at a great expense. Although the bill for thawing the tank still must be paid, the high price will now be hard to justify to the utility board.

Repairing Freeze Damage

After the cold weather is over, the tank should be drained and thoroughly inspected for any damage caused by the overflowing or freezing. If modifications are recommended to prevent recurrence of the problem, they should be done when the weather is warm, not next winter.

Ellipsoidal and spherical roofs that have sucked in due to vacuum or are depressed due to snow load can sometimes be repaired simply. Careful introduction of large volumes of low-pressure air into the tank will push the roof up to nearly its original contour. The method used should be designed and supervised by an engineer familiar with the structural design of tanks.

This is the first in a two-part series on cold weather operation of steel water storage tanks. Part two, which describes the causes of freezing and good tank design, will appear next month. ♦