



Preventing Ice Damage in Potable Water Tanks

A Resource For Operators

Introduction

Every winter, thousands of water utilities across the United States and Canada deal with the consequences of cold weather, such as main breaks and equipment outages. While these emergencies come without warning, they are obvious and visible when they do occur. But in other parts of the water distribution system, cold weather can create another risk that is hidden from view: ice accumulation inside water storage tanks. Often, the only time operators realize they have a problem with ice in their tanks is when it's too late: after a tank's interior is damaged or when the tank wall is punctured.

Few people climb and inspect their tanks in winter, so the extent of ice formation inside of water storage tanks is unknown. But rest assured: if you see ice on the lakes and ponds in your community, you can bet there is a cap of ice inside your storage tanks. And, it can be much thicker than the ice on your pond.

Problem

Ice commonly forms in a large collar between the high water level and low water level in your tank (Figure 1). This collar can be massive. In this image, the weight of ice in the collar alone is 140,000 lbs. This ice can pry ladders off the wall (Figure 2) and pull down level gauges and cathodic protection cables. And in doing so, it can tear a hole in your tank.

While the large load of ice clinging to the walls of the tank can be a concern, more damage is created when chunks of ice break off and ride up and down with the water level in the tank. These large chunks of ice scrape the walls of the tank (Figure 3), damaging tank coatings and exposing bare metal. In bolted tanks, the ice can shear off bolts and cause leaks.

A third area of ice danger lies in the headspace above the water. The vent at the top of the tank is a small but critical feature in your tank, allowing air to enter and leave the tank to replace the water during a drain or fill cycle. If that vent becomes blocked by snow and ice, the piston effect of the water leaving the tank will create a vacuum in the headspace, sucking in the roof and walls

of the tank. In extreme cases (such as during a fast draining episode, such as in response to a fire emergency), this can lead to the tank literally crushing itself (Figure 4).

Even partial obstruction of the air vent by ice can lead to damage to the vent screens, which can expose the tank to contamination by animals that can crawl inside and make their home in the tank.

In general, ice and large structures made out of metal don't get on well together. Just ask the Captain of the Titanic.

Source Water and Ice Formation

In general, utilities using surface source water for their system will experience greater water temperature swings during the year, and a greater propensity for ice formation in the winter. Surface source water temperatures are strongly controlled by climate, and during the winter, surface water temperatures can fall to close to freezing. In contrast, groundwater sources tend to have more stable temperatures year-round. This may reduce the risk of freezing in tanks close to the treatment plant. But for tanks at the end of the system, or with very low turn-over, that water can lose its heat.

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Figure 1



Figure 2



Figure 3



Figure 4: Ice can block tank vents, preventing air from entering while the tank is draining. This can cause low pressure inside the tank and can, as in this case, crush the tank.

Traditional Approaches for Managing Ice in Tanks

Utilities in northern climates have been managing ice formation inside water storage tanks for years using a range of traditional approaches.

Deep cycling. Some utilities try to increase the turn-over in their tanks during winter months to continually refresh the tank with warmer water from the treatment plant. This works best when there is a lot of flexibility in operations and tanks can be turned over easily. But this approach can lead to increased energy use to move the water around. And, if operations are constrained, this approach is not an option.

Pump-over. Some municipalities have pumps that pull water off the bottom of the tank and recirculate it to the top of the tank. If the pump is big enough, this can keep enough warm water in the top of the tank to prevent ice formation. But the amount of pumping energy needed to achieve this can be high, and this can lead to high operational costs.

Insulation. Some municipalities insulate their storage tanks. This reduces the rate at which ice forms in the tank by holding more heat inside. However insulating a tank can be expensive and, if turn-over is low, or weather conditions severe, this will only delay the inevitable formation of ice.

Heaters. Low turn-over tanks (such as fire storage tanks), or tanks in extreme northern latitudes are sometimes outfitted with heating systems. These resistance heaters directly heat the water to prevent freezing. Unfortunately, there are two drawbacks with heating systems. The first is obvious: they use a LOT of energy! Just imagine the cost increase of providing hot water in your house in winter... and multiply by hundreds.

The second drawback is less obvious but more important: warm water does not rise until it is about 6 degrees *above* freezing. A heating system inside a tank has to do more than keep the temperature above freezing: it has to heat the water hot enough so that it floats to the top of the tank on its own. This requires at least 6x the energy needed simply to keep the water from freezing.

A Better Approach: Active Mixing

In 2009, a municipality in Maine approached the ice prevention problem in an entirely new way. Old Town, Maine, just north of Bangor on the Penobscott River, had purchased two glass-lined storage tanks as a major upgrade to their distribution system. But within the first two winters, ice formation at the top of the tanks had scraped the glass lining off some of the interior of the tank, and caused some of the lining on the exterior to spall off as well (Figure 5). Anxious to eliminate ice formation in their tanks in future years, the municipality researched active mixing technology and purchased a submersible active mixer made by PAX Water Technologies.

Unlike the traditional approaches to reducing ice formation in tanks, active mixing forces warmer, denser water on the floor of the tank up to the top, and keeps all the water in the tank at a constant temperature. By keeping the water moving, operators at Old Town hoped to at least reduce the amount of ice in their tank.

Old Town installed the mixer in one of their two tanks in December of 2008 and left the other tank unmixed as a control. They also installed battery-powered cameras inside the tank, and periodically climbed the tank to monitor the progress of the trial.

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The results were remarkable. The tank without a mixer accumulated a large collar of ice, estimated to weigh over 100,000 pounds (Figure 6a). But the tank with the mixer remained ice-free (Figure 6b). This result was all the more remarkable because Maine had experienced its coldest winter in 50 years.

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Figure 5: Old Town, Maine purchased two glass-lined storage tanks but within the first two years, they saw damage to the glass lining of the tank (red circle).



Figure 6a: Interior view of the unmixed tank at Old Town, Maine. Each bolted panel is 4x10 feet. The ice load on the walls of this tank is estimated to be roughly 100,000 lbs.

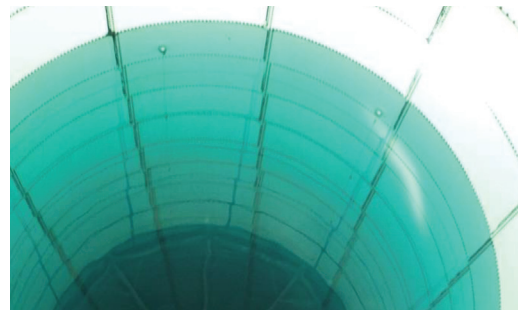


Figure 6b: Interior view of the tank with the PAX mixer at the same day as 6a. The tank remained ice-free during the coldest winter in Maine in the last 50 years.

Active Mixing + Heating: Preventing Ice and Controlling Temperature

In extreme northern latitudes, or for tanks with little or no turn-over, some additional source of heat may be required. For example, the operators and engineers of the Pouce Coupe Reservoir in Dawson Creek, British Columbia were well aware of the challenges in managing ice formation inside water storage tanks. The population of Dawson Creek is small but large amounts of water storage are required for fire prevention. Winter temperatures can be as low as -20 to -40 C. In their preliminary design for a new 0.75MG water storage tank, engineers specified four heaters using a total of 30kW to keep the water from freezing. However, after studying the results at Old Town and elsewhere, the engineers revised the design, integrating a PAX mixer into the tank design and cutting their heating power requirements to only 7kW. During the first winter that the new tank was in operation, operators observed no ice formation in the top of the tank.

Additional Benefit: Better Water Quality

In a number of cases, municipalities that installed submersible active mixers to eliminate winter ice also enjoyed an added dividend to this investment: better water quality year round. In Old Town, Maine, operators saw summertime disinfectant residual levels substantially improve after the installation of the mixers. The mixers eliminated the thermal stratification inside the tanks that led to high water age and high chlorine demand. And in Girdwood, Alaska, operators found that, in addition to eliminating ice formation in winter, their submersible active mixer was able to improve aeration in the tank, reducing an H₂S problem the municipality had with one of their water sources and lowering customer complaints.

Active Mixing: Power Makes the Difference

Ice prevention requires a powerful mixer. In general, a mixer that turns the tank over at least eight times a day is a good start. But weather conditions, tank turn-over, and the temperature of the inlet water are also important factors to consider, and greater mixing power (or a heater) may be necessary. While there are several active mixing technologies on the market, their mixing power can vary by as much as a factor of 10. Weak mixers may fail to deliver warm water all the way to the surface – or deliver too little water to keep a tank ice-free. Don't get "snowed" by manufacturers who don't have the evidence to back their claims.

Key Take-Away Points

1. Ice can form easily in water storage tanks and can cause damage or loss of a tank
2. Traditional methods for reducing ice formation inside tanks are partially effective and time and energy-intensive
3. An active submersible mixer can eliminate ice formation and protect tank assets from damage and can improve water quality year-round
4. Power is the key – mixers must be able to rapidly circulate the water inside the tank to be effective – puny mixers won't cut it.

References

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About the Author

Dr. Peter S. Fiske received his Ph.D. in Geochemistry from Stanford University in Geochemistry and Materials Science. He is the author of numerous technical articles as well as general industry articles that have appeared in *Opflow* magazine, *Water & Wastes Digest* and *Water Online*. As the CEO of PAX Water Technologies, Dr. Fiske oversees all technical and business operations of the company including new product development, product testing and validation and technical communications.