Protecting tanks from ice damage using submersible mixers

By Dr. Peter S. Fiske

Ice formation inside potable water storage tanks and standpipes is a common occurrence in the northern United States and nearly all of Canada during the winter. Depending on the average air temperature, the inlet water temperature and the amount of turnover, ice formation can range from a thin skin on the top of a water tank to a massive ice cap that weighs many tons.

While most people enjoy a little ice in their glass of water, thick ice in a water tank can spell disaster. Like an iceberg, a massive plug of ice can scrape the sides of a water tank as the water level fluctuates. If ladders and other internal hardware inside a tank become locked in the ice, the rise and fall of the ice cap can literally tear the hardware apart.

Numerous examples exist around the northern US of tanks that have been badly damaged or even ruptured by the action of ice (Figure 1). Even modest damage to tank coatings may require partial or complete overhaul, costing hundreds of thousands of dollars.

In above-ground water storage tanks, ice will typically form on the northern wall of the tank, starting at the water's edge. With continued cold weather, this ice will grow around the edge of the water, eventually forming a complete ring of ice.

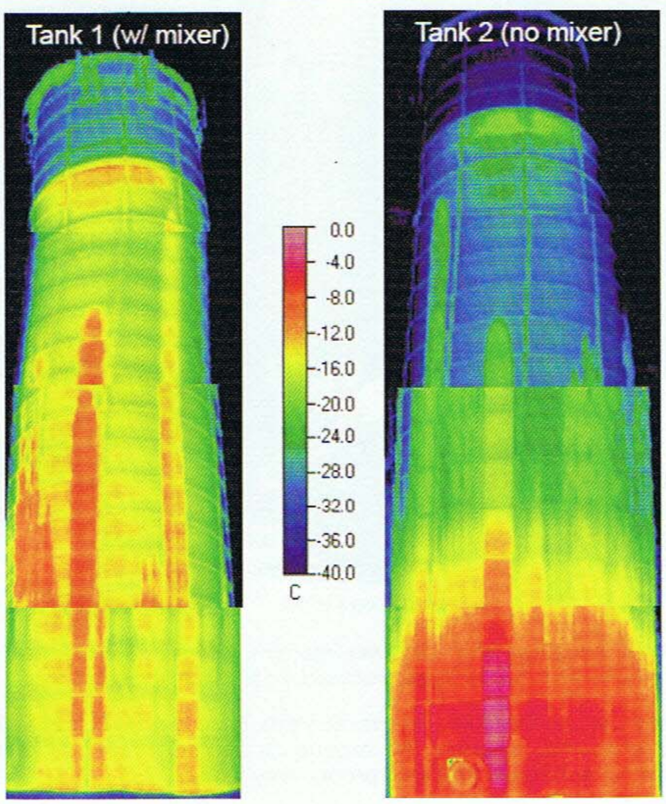
As the water level rises and falls within the tank, the ring of ice gets thicker and thicker. Eventually, even the centre of the tank becomes frozen over, but that ice is repeatedly shattered and refrozen by the piston-like action of the rising and falling tank level. The ring of ice expands as it freezes, pushing against the walls of the tank. When water levels fall, the massive ring of ice clings to the sides of the tank, pulling down on the tank walls. When water levels rise, the collar is submerged, and its buoyancy pulls the walls of the tank in the opposite direction. This stress can cause the tank coating to spall or, in extreme cases, can buckle the sides of the tank.

Figure 1. Buckled tank due to freezing.

The operators of the Old Town Water District in Old Town, Maine (outside Bangor) had been aware of the dangers of ice formation for many years. Nine years ago, they purchased two new glass-lined standpipes to increase their capacity. But after only two winters, one of the tanks showed evidence of ice damage; the glass coating on the exterior of the tank had spalled off due to stress from the ice frozen inside.

Water – a most unusual liquid

Nearly all liquids in nature become heavier as they cool. Water is different. When water cools over the last few degrees toward freezing (at atmospheric pressure), it actually becomes *less dense* due to molecular expansion. The solid it forms (ice) is 9% lighter than the corresponding liquid. This is why ice forms at the top of a body of water and grows downward. It is also why icebergs float. A water tank may have a daily supply of warmer water, but the buoyant force that would carry that warm water to the top of the tank is impeded by the density change as the water cools.



Fiqure 2. Side-by-side infrared images taken at night reveal the difference between a mixed and an unmixed tank. Without a mixer, fresh warm water remains trapped at the bottom of the tank. In contrast, a well-mixed tank has more uniform temperatures throughout.

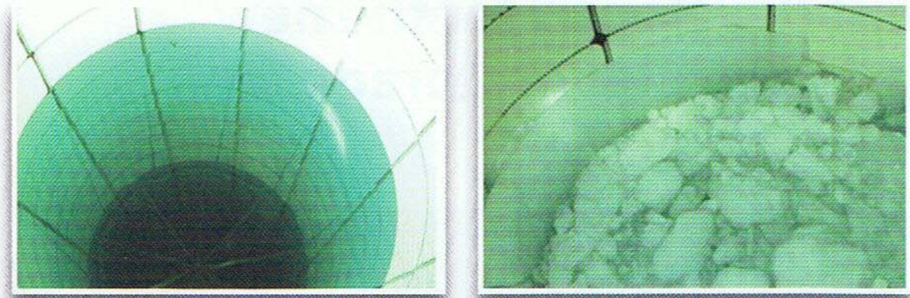


Figure 3. Despite several months of sub-freezing temperatures, the tank with the submersible mixer (left) remained ice-free. In contrast, the unmixed tank (right) had thousands of pounds of ice, which would not disappear until late spring.

The operators at Old Town realized that, while the water coming into the tanks from the plant was 42-45°F, the amount of turnover and low velocity were not sufficient to disrupt the chilled layer of water at the top of the tank. As a result, the tops of the tanks would freeze solid winter after winter.

In the late fall of 2008, in an attempt to reduce ice formation inside the tank, the operators began a trial to evaluate a small submersible mixer made by PAX Water Technologies inside one of the two tanks. They theorized that, if the warmer inlet water could be physically

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transported to the top of the tank, it would greatly reduce the rate at which ice would form. The PAX Mixer's patented impeller design is engineered to create a collimated vortex that transports fluid to the top of a water tank using a minimum of energy.

Unfortunately, by the time the mixer was installed, Maine was already in the grip of one of the coldest winters on record. Ice had already formed on the interior walls of the tank and, once drained, massive piles of ice had to be cleared from inside the tank. Once the mixer was installed, the tank was refilled. The mixer was turned off for a period of one week, which allowed a four-to-six-inch thickness of fresh ice to form at the top of the tank.

In early January 2009 the mixer was turned on, and the internal condition of the mixed and unmixed tanks was observed. In mid-February, the ice in the tank with the mixer had broken up, whereas the ice in the unmixed tank remained. After eight weeks, the mixed tank was completely ice-free, while the tank without the mixer remained capped with a thick rim of ice (Figure 3).

The teams also used an infrared camera to monitor the temperature profile in both tanks. As they suspected, the unmixed tank had an inverted thermal profile; the warmest spot was at the base where the inlet water came into the tank (Figure 2). But at the top of the tank, the temperature was below freezing. In contrast, the tank with the mixer had a uniform temperature all the way to the water surface.

The trial at Old Town will continue through the summer, where the active mixer will help to prevent summer thermal stratification and improve overall water quality.

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Photos courtesy Utility Service Company Inc., Peter Fiske and Bruce Stevens.