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Ice Prevention In Potable Water Storage Tanks With Solar-Powered Active Mixing

White Paper

Updated August 2013

Ice buildup in a tank before active mixing

Ice cut out to install a SolarBee mixer

Thin edge ice during active mixing

Overview

"Water bodies, like human bodies, require good circulation to function properly" (Hudnell, 2009). Quiescent waters in potable water storage tanks are associated with water quality problems such as thermal stratification, biofilms, excessive disinfection byproducts and disinfectant residual loss. Ice formation in distribution-system reservoirs is another challenge faced by water utilities in northern climates during winters. Thick layers of ice often form at the surface in storage tanks during prolonged periods of subfreezing weather. Steel tanks can expand during ice formation, causing structural damage and water leakage. The vertical movement of huge ice chunks with inflows and outflows may further damage the tanks. This report discusses the causes of ice buildup in potable water reservoirs, and describes applications of Medora Corporation active mixing technology to prevent excessive ice formation.

Background

Most potable water storage tanks were built before the water-quality benefits of circulation and mixing were fully appreciated. Primary considerations during construction were excess storage capacity for fire protection, pressure regulation, and future growth, and efficiency of water influent-effluent transfer. Both considerations resulted in low rates of passive mixing within the tanks. The excess capacity led to daily usage of small portions of capacity, thereby limiting passive mixing. The use of single pipe influent-effluent designs with the ingress-egress point typically located at the base of the tank further limited passive mixing. Passive mixing was limited even when separate influent and effluent pipes were positioned on opposite sides of the tanks (Figure 1).

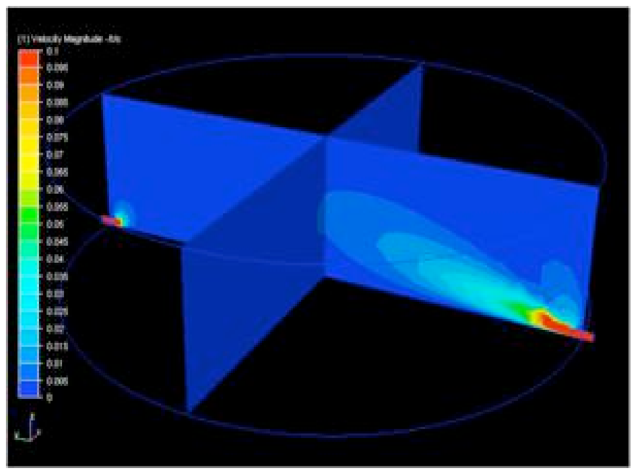

Figure 1. *Computational Fluid Dynamics Modeling of a 2 MG tank with separate influent and effluent pipes indicates that most of the water is stagnant (blue) even during strong inflow (right, red) and moderate outflow (left, red).*

Ice formation

Insufficient mixing enables water to become thermally stratified within the tanks. During warm seasons, warmer water stays in the upper portion of the water column resulting in long retention times and associated water quality problems. Conversely during sub-freezing weather, temperatures in the lower portion of the water column are warmest because influent waters, typically about 11° C from a groundwater source or 4° C from a lake, are the primary source of heat. When influent volumes are low, influent water temperature declines quickly to 3-5° C, and the new water stays in the lower portion of the water column because the density of water is greatest at about 4° C. Water temperatures in the tank decline with increasing elevation until ice forms wall-to-wall on the surface. Subsurface ice continues to form, often reaching thicknesses of 1-2 ft.

Medora Corporation mixers in potable-water storage tanks

All Medora Corporation mixers designed for use in potable-water storage tanks are certified to ANSI/NSF Standard 61, thereby ensuring that dangerous contaminants do not leach into the drinking water.

SolarBee mixers range in size from the SB500PWc suitable for use in the smallest tanks to the SB10000PW such as those deployed in San Francisco's 87.3 MG Sunset Reservoir (Hudnell, 2009a). Several of the small-frame models are collapsible, enabling them to be inserted into the tank through hatches as small as 18 in. in diameter. All units operate continuously using one or more 80-watt solar panels mounted on the tank roof and a battery. Unit function can be monitored through SCADA outputs or other optional communication systems. Medora's design goal in sizing and recommending a mixer is to circulate water throughout the entire tank with complete turnover occurring within 48 hours (Figure 2). Medora's complete mixing eliminates dead spaces and brings disinfectant into contact with the boundary layers of the walls and floor to remove biofilms and prevent their formation.

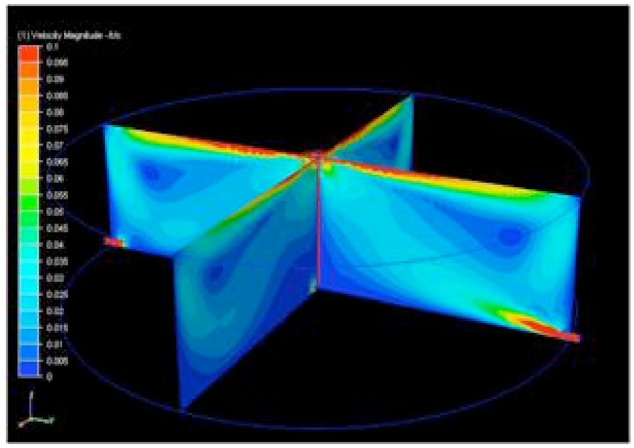

Figure 2. *Computational Fluid Dynamics Modeling comparable to that shown in Figure 1 except that a SB1250PW is circulating the 2 MG of water. Continual mixing eliminates thermal stratification and prevents ice buildup.*

Medora Corporation mixers for ice prevention

Of the more than 300 Medora Corporation mixers installed in potable-water storage tanks as of November 2009, more than 40 were installed across the northern U.S. Researchers at Medora Corporation's headquarters in Dickinson, ND, among the coldest areas in the U.S., are systematically collecting temperature, ice thickness and other data to objectively quantify the efficacy of active mixing for ice prevention.

Utility personnel currently using SolarBee active mixers unanimously report an ice-free area around the mixer. They consistently report that when ice is present, it is limited to a thin layer on the perimeter, particularly on the northern side. The area of ice coverage is determined by a steady-state relationship between heat loss through evaporation and heat gain through influent. A thin layer of ice expands from the northern perimeter, reducing evaporative heat loss, until balance is achieved.

Photographs from the bolted-steel reservoir in the Village of Elizabeth, IL, illustrate the ability of mixing to prevent ice formation. The reservoir is 40 ft. high and 42 ft. in diameter (Figure 3).

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Figure 3. *Bolted-steel reservoir with solar panels mounted on the roof to power a SolarBee mixer*

Maximum capacity is 400,000 gal, and mean daily influent is 100,000 gal. Ice buildup across the surface caused bolt holes to be stretched and water leakage prior to 2008. The top-to-bottom temperature differential in the tank was approximately 3° C before activating the mixer on February 12, 2008 (Figure 4).

Figure 4. *Holes can be broken through ice up to about 6 in. thick to install a SolarBee mixer.*

Long Distance Circulation

The ability of SolarBee mixers to create long distance circulation was demonstrated in a study of harmful algal bloom suppression conducted in source waters at three drinking water utilities (Hudnell, et al., 2009). Strong bloom suppression occurred with a mean unit spacing of 1 unit per 35 acres, indicating that each unit pulled in water from a distance of over 200 yards. The patented technology of a steel plate suspended 1 foot below the hose intake causes water at that density layer to be drawn in radially with near-laminar flow. The largest SolarBee units pull water to the surface at a rate of 10,000 GPM. Water departs from the units without turbulence at the surface both above and below a distribution dish. The outflow combines with other surface currents to redistribute water over the 35-acre area. The key to creating long distance circulation is the radial, near-laminar flow input. This patented design is used in potable water SolarBee mixers with the intake set at the bottom of the tank. This design and deployment combination ensures that water is circulated in all parts of the tank, including the boundary layers of the walls and floor.

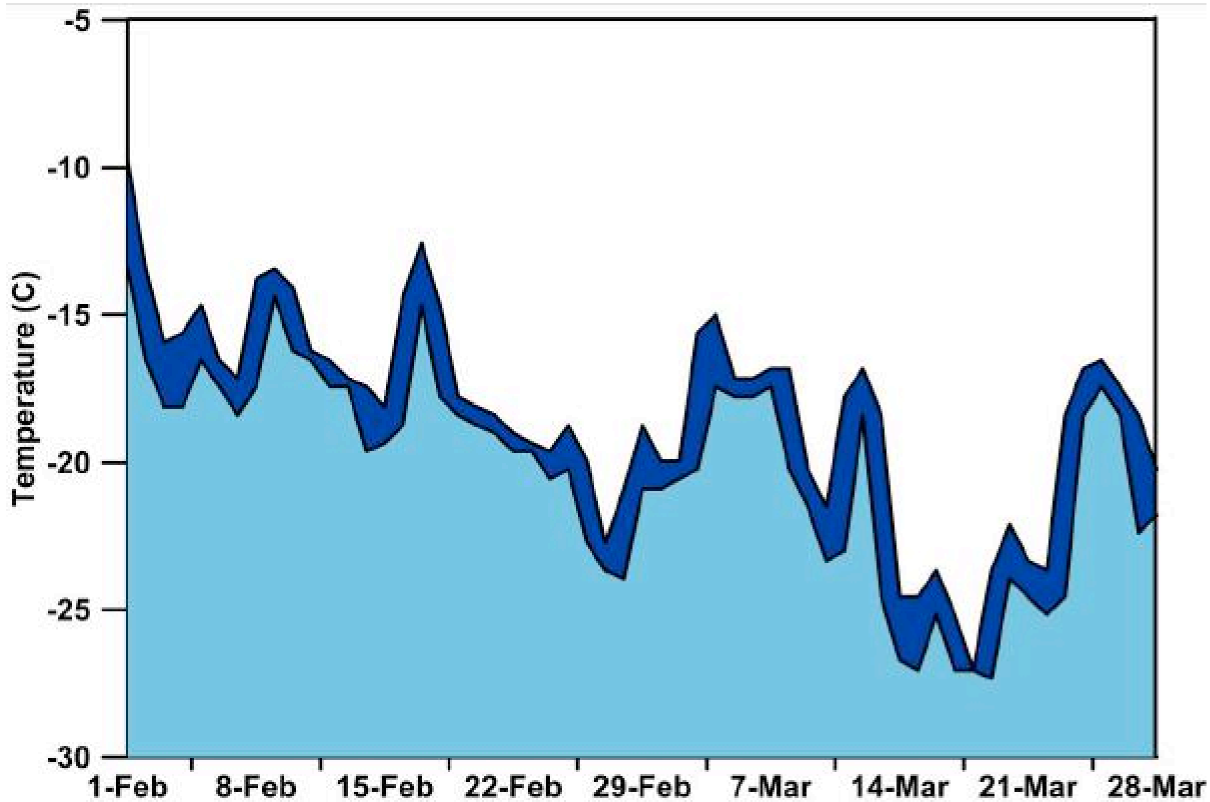

Figure 5. *The top line (dark blue area) shows the mean daytime temperature, while the bottom line (light blue area) depicts the mean nighttime temperature during February and March, 2008, in Central Illinois.*

The service crew returned to the reservoir on March 5, 2008, during a prolonged period of constantly subfreezing temperature (Figure 5). The top-to-bottom temperature differential had decreased to 0.3° C. A thin crescent-shaped layer of surface ice rimmed the north side of the tank (Figure 6). No ice was present on the south side of the tank (Figure 7).

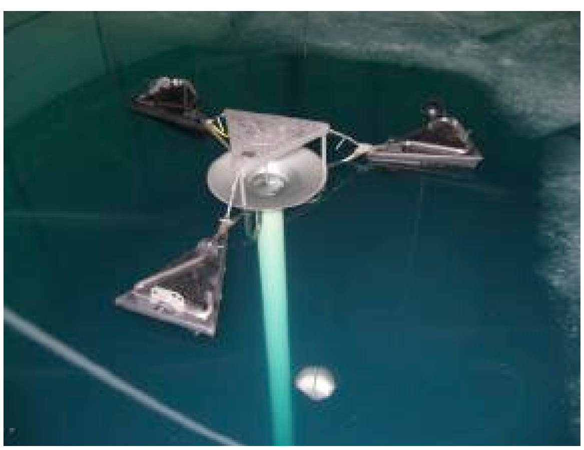

Figure 6. *Thin ice on the north side of the bolted-steel reservoir during SolarBee active mixing, 3/05/2008*

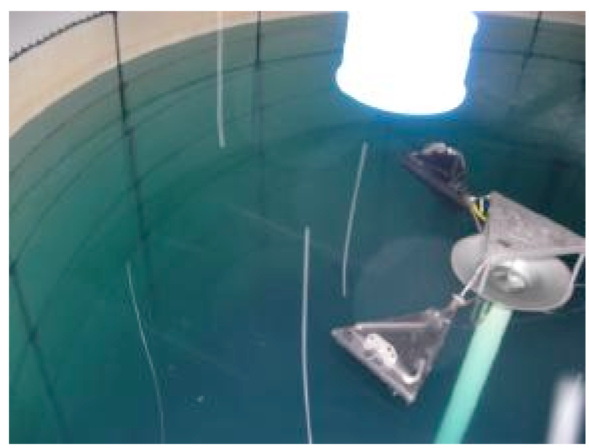

Figure 7. *No ice on the south side of the bolted-steel reservoir during SolarBee active mixing, 3/05/2008*

Medora Corporation's active mixing year round
Stratification reverses as winter turns to spring such that the warmer water stays at the top while the cooler influent water mixes with bottom water until withdrawal. Disinfectant residual levels decline in the upper water as mean age increases. Residual reduction increases the risk for microbial growth, nitrification when chloramine is used, other disinfectant byproduct formation and associated human health risks. Year round active mixing keeps tanks destratified and provides consistent disinfectant residuals. Should disinfectant boosting be needed, for example when boundary-layer biofilms are degrading after mixing commences, circulation evenly distributes the disinfectant throughout the tank. SolarBee's active mixing is the most efficient method for meeting the requirements of the U.S. Environmental Protection Agency's (2008) new Stage 2 Disinfectants and Disinfection Byproducts Rule.

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