PAX WATER TECHNOLOGIES™



How to Select and Specify Mixers for Potable Water Storage Tanks

A Resource For Engineers and Operators

Introduction

Mixing in potable water storage tanks is increasingly recognized as an important factor for improving water quality and protecting tank assets. Thorough mixing eliminates thermal stratification and ensures uniform conditions in tanks. This has been shown to lower overall disinfectant residual demand, reduce the risk of nitrification and enable safe, reliable boosting of residual disinfectant. Additionally, mixing can protect and preserve tank assets by preventing the formation of ice (which can scrape tank coatings or puncture tanks), and lowering summertime headspace temperatures (which reduces corrosion rates).

But how much mixing is "enough" for each application? And how do tank size, shape and frequency of fill and drain cycles affect the power needed to completely mix a tank? What are the consequences of selecting a mixing technology that is too weak for a given application?

Relationship Between Tank Volume, Tank Turnover and Mixing Power

The size or volume of a water storage tank is a principal design consideration when considering mixing. Published scaling relationships show that blend time (the time required to take an initially unmixed volume and blend it to a homogeneous condition) scales linearly with the volume of tank.

The rate of turnover in a tank also determines how much mixing power is required to achieve blended conditions. Any mixing system must be able to achieve a fully blended condition in less than the cycle time of the tank. Most water storage tanks have a fill/drain cycle that is 24 hours long. Thus, many mixing systems are specified to achieve fully-blended conditions in less than 24 hours. However, if a tank is cycled at a higher frequency, the required minimum blend time will be shorter, and the required amount of mixing power will be higher.

To achieve "miscible blending" (the process of blending two fluids that mix fully with one another, such as hot and cold water), literature studies suggest that the fluid within a tank must be completely turned over at least six times[1]. This rule of thumb allows engineers to estimate a required pumping rate for a mixer through the following equation:

Minimum pumping rate (gpm) = 6v/f

where *v* is the volume of water in the tank in gallons, and *f* is the frequency that the tank cycles in minutes (24 hour cycle time = 1,440 minutes).

For example, to achieve miscible blending in a 500,000-gallon water storage tank that cycles every 24 hours, an effective mixing system must pump at least 2,083 gallons-per-minute (GPM) to achieve six tank turnovers in the 24-hour period:

(6 x 500,000)/1,400 = 2,083 GPM

Engineers and operators should insist on blend time data to verify pumping rate claims."

If the same tank cycled every 4 hours, the mixing system would have to achieve blended conditions in 1/6th the time, requiring a pumping rate of 12,500 GPM:

(6 x 500,000)/240 = 12,500 GPM

Table 1 provides some estimates of the pumping rate required for a mixing system as a function of tank size and rate of tank turnover.

Tank Volume (Gal)	GPM Pumping Required (24-hour cycle)	GPM Pumping Required (4-hour cycle)
300,000	1,250	7,500
500,000	2,083	12,500
1,000,000	4,166	25,000
4,000,000	16,667	100,000

For very large tanks, or for tanks that cycle at a high frequency, fully blended conditions may not be practicably achieved using any mixing system. In such cases, operators may simply wish to ensure that a mixing system improves circulation and eliminates large-scale short circuiting.

While this equation can help engineers estimate the minimum pumping rate to achieve miscible blending in a tank, determining the actual pumping rate of various mixing technologies is not easy. Some manufacturers claim extremely high pumping rates based solely on computational fluid dynamics (CFD) models. Unfortunately, uncalibrated CFD models drastically over-estimate actual pumping rates for mixers. The only reliable test of a mixer's performance is temperature and/or chemistry blend time data from a real-world installation. Therefore, engineers and operators should insist on blend time data to verify pumping rate claims.

Relationship Between Tank Aspect Ratio and Mixing Power

A tank's height-to-diameter (H/D) ratio can have a large influence on the mixing power required. For example, in one study, a 9 MG tank with a H/D ratio of 1:20 was blended to a uniform condition in less than 24 hours. The same mixing system in a 4 MG tank with a H/D ratio of 3:1 failed to achieve mixing after operation for three weeks. Tanks with a H/D ratio greater than 3:1 require more mixing power to achieve a blended condition.

Relationship Between Process Goal and Mixing Power

The mixing power required is a function of the process goal desired. The various process goals, and the relative mixing power required, are summarized in Table 2:

Process Goal	Required Mixing Power
Thermal de-stratification	Low-Moderate
Lowering nitrification risk	Low-Moderate
Blending a chemical dose	Moderate-High
Ice-prevention	Moderate-High
Aeration for THM removal	High

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Precise boundaries on the required amount of mixing power (or pumping rate) required to achieve a process goal are difficult to apply. In some cases, an initial mixer selection may be found to be insufficient to achieve the process goal under all conditions (or the process goal is more extreme than originally estimated). In these cases, an upgrade to a more powerful mixer may be necessary.

Quantifying Mixer Performance

Once installed, mixer performance can be determined by several tests:

Thermal blend time. Thermal blend time can be measured by deploying temperature sensors within the tank and measuring the time required to take the tank from an initially stratified condition to a condition of thermal homogeneity. This blend time measurement is relatively easy to carry out provided there is access in the tank to position the temperature probes in a location that is generally representative of the tank conditions (away from walls and inlets). Figure 1 shows an example of blend time data recorded by the probes[2].

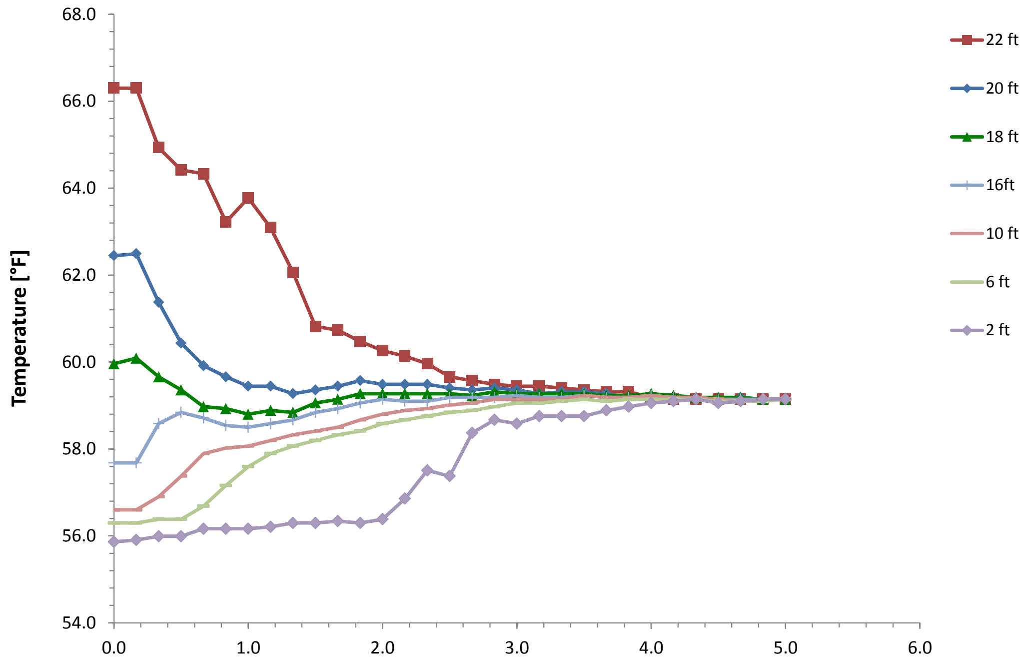

Figure 1. Data from the PAX Water Mixer in a 500,000-gal tank shows that the water temperature at each level converged within 4 hours.

> The most reliable procedure to measure the % of TTHM reduction is to compare samples taken from the tank with the mixer and ventilation on versus off over a period of time."

Chemical blend time. A more demanding test of mixer performance is the measurement of chemical blend time. A dose of (chlorine) disinfectant is introduced into the isolated tank and allowed to settle on the bottom. The mixer is then turned on and water samples are taken from various depths and locations in the tank. While this involves multiple manual samples, the results can clearly resolve whether a specific mixer is sufficient to achieve the required process condition for controlled chemical dosing. However, as with thermal sampling, there must be sufficient access points in the tank to allow for sampling at different depths and locations.

De-icing observation. The prevention of ice formation is easy to verify by visually inspecting the interior conditions of the tank once the mixer has been turned on and operated[3]. The presence of a thin skin of ice may pose little or no threat to the interior of a tank. However, large chucks of ice, or a collar of ice clinging to the interior of the tank, indicates insufficient mixing.

THM removal. Verifying the level of THM removal from mixing (operated in conjunction with forced ventilation) requires multiple measurements of total THMs in the tank. Several analytical methods exist. THM removal rates cannot be directly determined by simply measuring TTHM levels entering versus leaving the tank because there is some unknown level of THM formation within the tank that must also be taken into account.

The most reliable procedure to measure the percentage of TTHM reduction is to compare samples taken from the tank with the mixer and ventilation ON versus OFF over a period of time. Starting with the mixer and ventilation system OFF; TTHM sampling should be taken once a day (at roughly the same time of day) for 2-4 days. Then, the mixer and ventilation system is turned ON. Sufficient time must be given to allow the tank (and TTHM levels) to reach steady-state conditions. A good rule of thumb is that the required equilibration time between sets of measurements is 2x the average water detention time in the tank. In other words, if the tank has an average detention time of 2 days, operators should wait at least 4 days before taking sets of samples after the mixer and ventilation system has been turned OFF or ON. Once steady-state conditions have been achieved, the tank is again sampled daily, at the same time each day, and for 2-4 days. The average TTHM level with the mixer and ventilation system on versus off provides a good measurement of the percentage reduction achieved by mixing and ventilation. Repeating this cycle of measurements several times will result in a reasonably accurate measurement of mixer (and ventilation) performance for this application[4]. Active mixing can also be used to reduce levels of other volatile compounds such as CO_2, H_2S, and VOCs[5]. A similar protocol can be adopted to verify performance, provided a robust analytical method is available.

Examples of Adequate Versus Inadequate Mixer Performance

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Few side-by-side studies of different mixing technologies have been performed. But those that have been performed show large differences in mixing capability, despite equipment providers claiming comparable performance.

Example 1. Thermal de-stratification in a 4 MG water tank.

A municipality in Southern California had a pair of 4 MG steel storage tanks at a single location. These tanks were operated in parallel and both received the same amount of water and were exposed to the same amount of sunlight. One tank had a solar-powered, floating mixing system. The other had a grid-powered submersible mixing system.

Figure 2 shows the thermal profile of the tank with the submersible mixing system. When the mixer was turned OFF, the tank quickly became thermally stratified. When the mixer was turned ON, the thermal stratification was eliminated and temperatures at various depths within the tank were uniform to within 0.5 °F.

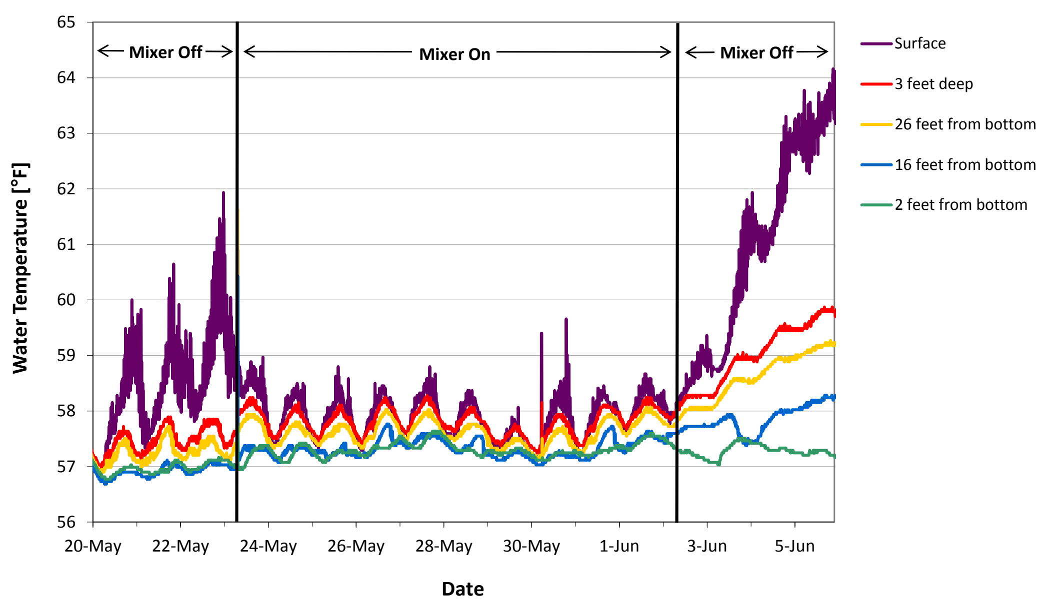

Figure 2. Data from the PAX Water Mixer in a 4MG tank shows that the water temperatures became uniform within 0.5 °F. When the mixer was turned off, the tank quickly became thermally stratified.

Figure 3 shows the other tank with the floating mixing system. Even though the mixing system was in operation during this entire time period, persistent thermal stratification of 5 °F remained in this tank.

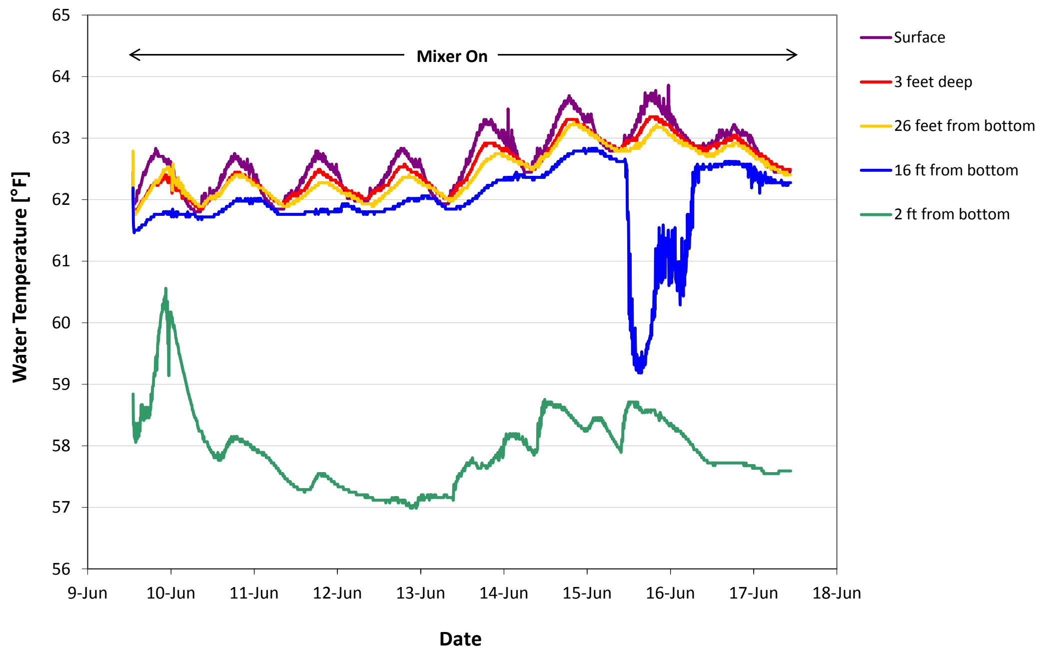

Figure 3. Data from a floating mixing system in a 4MG tank shows that the mixer was unable to eliminate thermal stratification. A 5 °F temperature difference between the upper and lower water layers persisted.

» The more expensive mixing system was able to achieve a fully-blended condition within the required 24-hour period, the cheaper mixer failed to even approach a well-mixed condition after operation for 38 hours."

Example 2. Disinfectant blending in a 4 MG water tank.

Another municipality in Southern California evaluated two different submersible mixing systems for use in 4 MG water storage tank. This tank was occasionally dosed with disinfectant and operators wanted to test the speed at which each mixing system could blend the dose. The mixing systems differed in price by a factor of 3.

The tank was isolated and two doses of hypochlorite were introduced. Because of the higher density of hypochlorite solution, these doses fell to the floor of the tank and created a layer of high disinfectant at the bottom. Operators then turned ON each mixing system and sampled at multiple depths and locations every four hours until all residual readings were uniform (indicating complete mixing).

The more expensive mixing system was able to achieve a fully-blended condition within the required 24-hour period (Figure 4). However, the cheaper mixer failed to even approach a well-mixed condition after operation for 38 hours (Figure 5).

Both manufacturers claimed pumping rates sufficient to achieve the process goal. However, the data showed there was factor of 10 difference in blend time (and thus actual pumping rate). This illustrates the importance of calibrating manufacturers' claims with real-world blend time data.

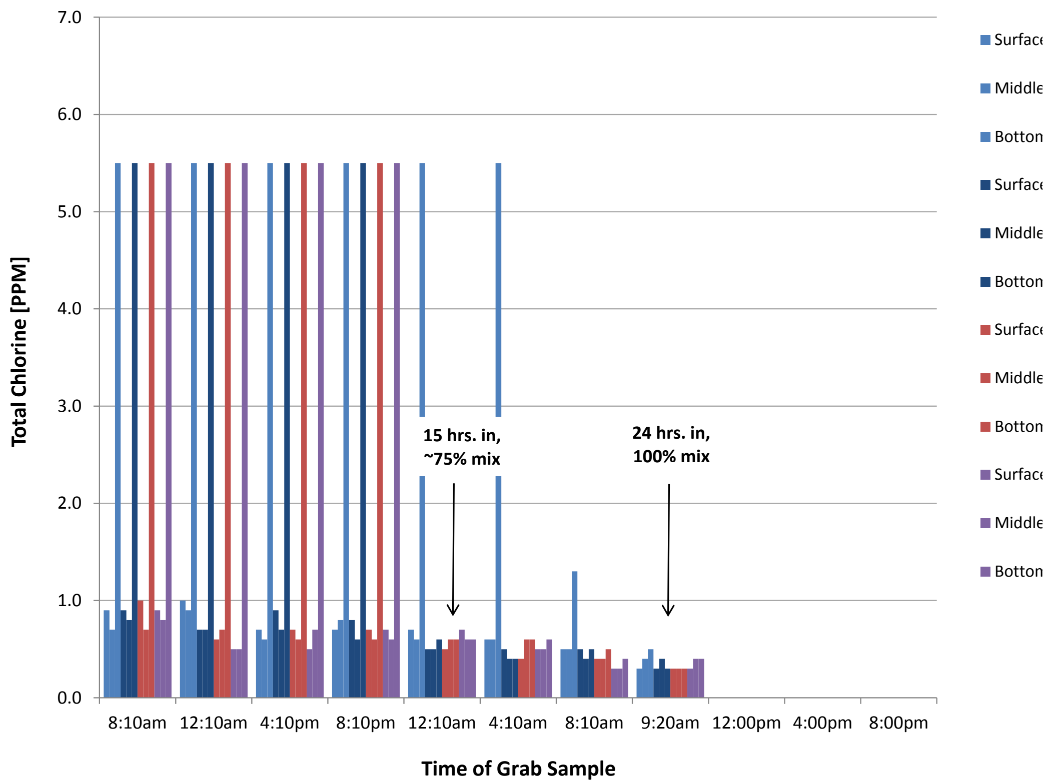

Figure 4. Data from the PAX Water Mixer in a 4MG tank dosed with 50 gallons of hypochlorite shows that water chemistry became uniform within 24 hrs.

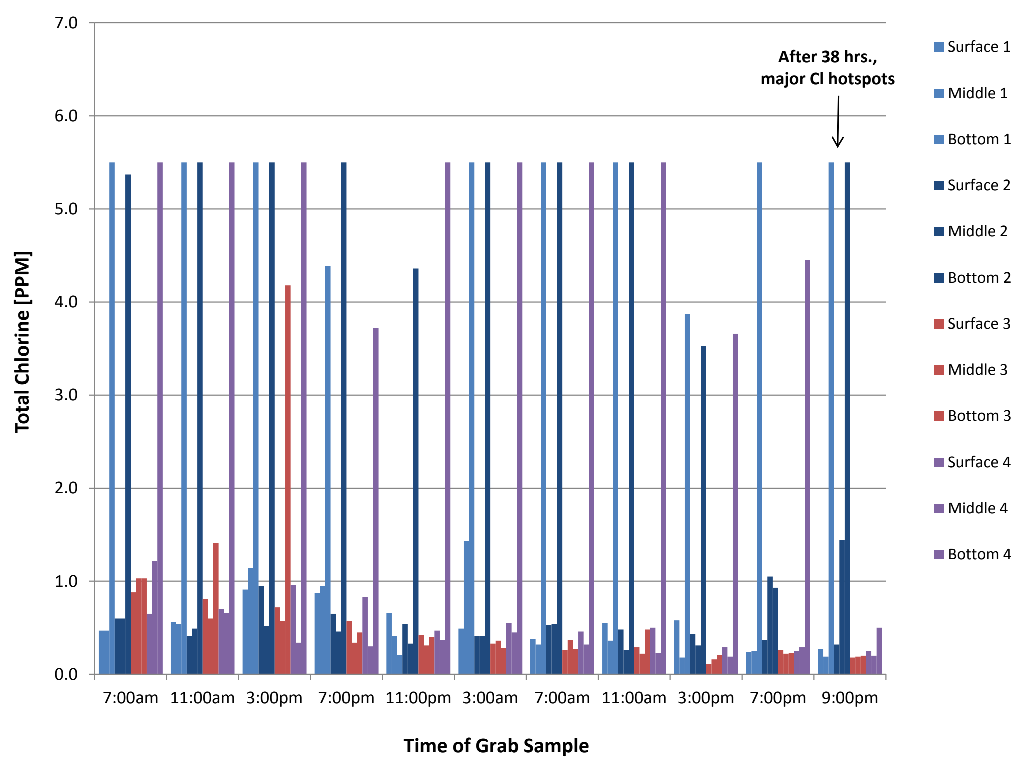

Figure 5. Data from a cheaper submersible mixing system in a 4MG tank dosed with 50 gallons of hypochlorite shows that water chemistry never became uniform, even after 38 hrs. of mixer operation.

Key Take-Away Points

1. Selecting a tank mixer requires consideration of a number of factors, including a tank's volume, shape, turnover and the process goal. Specifying a mixer solely on the basis of tank volume may result in a failure to achieve required process goals.
2. Pump rate can be a useful metric for determining mixing power, however, manufacturers' claims should be calibrated with real-world blend time measurements (temperature and/or chemistry).
3. Mixers vary in price by a factor of 3, but mixers can vary in performance by a factor of 10 or more. Price comparisons are only valid when normalized by equivalent mixer performance. Blend time measurements are the most reliable metric for evaluating mixers.

Endnotes

1. Hemrajani, R.R., 2000. Mixing and Blending. *Kirk-Othmer Encyclopedia of Chemical Technology.*
2. Fiske, P., 2011. Mixing Restores Disinfectant Residual and Prevents Nitrification (Redwood City, CA). PAX Water Technologies.
3. Fiske, P., 2014. Mixer Keeps 100,000-Gal Elevated Tank Ice-Free During "Polar Vortex" Winter Storm (Atwater, MN). PAX Water Technologies.
4. Fiske, P., 2014. Mixing and Aeration Reduce THM Levels by 53% in an 8 MG Water Tank (Rockville, MD). PAX Water Technologies.
5. Fiske, P., 2011. Keep Ice from Ruining your Water Tank – Results Using Active Mixers. *BC Watermark.*