

Designing Storage Tanks for Water Distribution Systems



Designing Storage Tanks for Water Distribution Systems

By

Pete Peterson, PE

PDHLibrary Course No 2022003
3 PDH HOURS

DESIGNING STORAGE TANKS FOR WATER DISTRIBUTION SYSTEMS

Storage tanks are a necessary part of all potable water systems. For all but the very smallest systems, these tanks store large quantities of water, from 10,000 gallons in very small systems to over 5 million gallons in large systems. These tanks store water for multiple purposes in a drinking water system. They provide storage so the water treatment plant does not have to provide the instantaneous peak flow and allow the treatment plant to operate at a much more constant rate. They also allow the treatment plant to operate less than 24 hours a day during almost all demand conditions. They provide additional storage to fight large structure fires in this emergency condition. This course will discuss factors for the two different types of storage tanks (ground storage and elevated storage) along with the advantages and disadvantages of each. It will also discuss the challenges associated with maintaining high quality water in a large tank and methods to accomplish this task.

TYPES OF TANKS

Ground Storage vs. Elevated

There are two basic types of tanks – ground storage tanks and elevated tanks. A ground storage tank is typically designed so the bottom of the storage volume is at approximately the ground level. There are three different types of ground storage tanks. The first type is an above ground tank which is probably the most common. The second type is a below ground tank and the third type is referred to as a standpipe. A standpipe is just a regular ground storage tank with the difference being that the height of the tank is greater than the diameter of the tank and therefore it's a tall, slender tank and this configuration is called a standpipe.

Materials

There are two different materials that are commonly used in storage tanks. Concrete is used for ground storage tanks and sometimes for the base of elevated tanks. Steel can also be used for ground storage tanks as well as for elevated tanks. Almost all elevated tanks are constructed from steel. In either case the materials need to be protected from corrosion and there are a variety of approaches related to protecting these materials from corrosion.

Ground Storage Tanks

Figure 1 shows a typical ground storage tank. This tank is constructed of bolted steel plates. On the front of this tank there is an overflow pipe. The overflow pipe is a necessary feature for all storage tanks whether they're ground storage tanks or elevated tanks.



Figure 1.

Figure 2 shows a buried concrete tank with only a small portion of the top of the tank exposed. Note at the top of the tank there is a vent and there is also an access hatch for the tank. This tank also has a fence around it to reduce the potential for vandalism because the top of that tank is so easily accessible from the adjacent ground. This tank is located on a hillside above the pressure zone that it serves.

Figure 3 shows a concrete tank located on a hill adjacent to the community that it serves. For this type of tank to provide the most function the elevation of the hill needs to be high enough that you get adequate pressures at all service locations. Note in Figure 3 that tank is not located at the top of the hill but rather just far enough up the hillside to provide desired pressures.

Figure 4 shows an example of a standpipe. Note the height of the tank is much greater than the diameter of the tank. Standpipes are used in locations where the high spot in the area is not quite high enough to provide adequate pressure but is high enough so an elevated tank is not required. One of the challenges of a standpipe is insuring adequate turnover in the tank, since adequate pressure is commonly only available when about the top half of the tank is used and the bottom half always remains full.



Figure 2



Figure 3



Figure 4

Elevated Tanks

Many different sizes and shapes of elevated tanks are available. Very small tanks can be used to serve small rural communities. Figures 5 and 6 show a couple examples of very small elevated tanks that are used to serve small communities. Both of them these examples use separate supports for the tank and any center column that includes the pipe that provides water to the tank.



Figure 5

Larger elevated tanks are also commonly available and used. Figure 7 shows a large elevated tank with 10 support legs. This large number of support legs is due to the weight of the large volume of water that's being supported. Figure 8 shows another example of a large elevated tank this one with a pedestal for vertical support. Inside the pedestal he is the pipe that provides water to the tank. The pedestal is a structural member that provides the vertical support for the weight of the water in the tank above. One advantage of this type of elevated tank configuration is the space at the ground level inside the pedestal can be used for storage or as a maintenance area for staff.

There are some limitations on the size of larger tanks primarily due to the increasing weight of the water as the size of the tank gets larger. There are also limitations on the height of tanks primarily due to structural considerations. Therefore it's always recommended that even elevated tanks be located in areas of relatively high ground elevations rather than in the very bottom or lowest parts of a service area.



Figure 6



Figure 7



Figure 8

Advantages and disadvantages of tank configurations

There are a number of advantages and disadvantages of each type of tank. With ground storage tanks one of the advantages is it is typically less expensive per gallon of water stored than an elevated tank would be. A ground storage tank may still need a very significant foundation to support the weight of the water however. Ground storage tanks can also generally be larger than elevated tanks. It is uncommon for an elevated tank to be more than a few million gallons in size but a ground storage tank can easily have a capacity of 5 or 10 million gallons.

Another advantage of a ground storage tank is access for maintenance including painting and cleaning. With all of the components of the ground storage tank located near the ground it is possible to access all of those components using ladders or relatively small lifts.

Ground storage tanks are often placed on a hill to provide adequate static pressures. This can be an advantage by reducing the cost of the tank however the economic advantage diminishes as the location of the hill gets farther from the center of the service area. A long transmission line to the tank reduces the economic advantage of the ground storage tank so if the hill is located far from the service area an elevated tank may be more economical in total project cost even though the tank itself might be more expensive. When a single transmission line is used that often means that the tank level does not fluctuate very much during the day and therefore water age can become a significant issue.

Elevated tanks are typically more expensive per gallon of water stored. Elevated tanks are also generally more limited in maximum size. Maintenance of an elevated tank is usually much more challenging and much more expensive because it requires specialized equipment and specialized personnel due to the height of the tank. There are also more components of an elevated tank due to the support system that's necessary. In some communities the aesthetics of an elevated tank are considered undesirable because the tall tank will block views of the surrounding landscape.

One of the advantages of an elevated tank is it can be located near the center of the distribution system. This ensures better turnover of the tank which reduces water age and improved water quality and also provides more effective flow distribution throughout the system. Where large flows are required for fire flow requirements having the storage close to the center of the distribution system allows for smaller pipes throughout the distribution system as opposed to a ground storage tank located more remotely from the service area which may require a much larger transmission line to provide service. This also results in much shorter transmission lines from the distribution system to the elevated storage tank. Even with a single line feeding the elevated tank the short length of transmission line makes water age a more manageable issue.

MATERIAL

Ground Storage Tanks

Many ground storage tanks are constructed using standard cast in place concrete. Another option for concrete tanks is to use prestressed concrete. A prestressed concrete tank requires more specialized contractors but could still be a less expensive tank due to the advantages of prestressed concrete. Concrete tanks are often preferred for ground storage tanks because the maintenance of a concrete tank tends to be quite low. While the concrete tank still needs to have an appropriate interior and exterior coating small failures of the coating do not result in the potential for holes in the tank wall like they do in the case of steel tanks. Standards for concrete tanks are included in American Water Works Association (AWWA) D110 and D115.

Steel is also quite commonly used for ground storage tanks. In some cases the steel plates are welded together providing a complete shell for the storage tank. This process requires qualified welders since even small inconsistencies in the welds can result in potential failure of the tank wall. Another option with steel tanks is to provide a bolted steel tank where the steel plates have flanges and a gasket is placed between each plate and the plates are bolted together. One type of bolted steel tank is a glass lined bolted tank where each steel plate has a glass lining fused to the steel to reduce the potential for corrosion. One of the primary disadvantages of steel tanks is relatively high maintenance costs. With welded steel tanks and bolted steel tanks both the inside and the outside of the tank needs to be painted on a regular basis because the integrity of that coating surface is critical to eliminate the potential for leaks through the wall of the tank. In order to complete painting for maintenance it's necessary to take the tank completely out of service, dry it, clean it, provide appropriate surface preparation, paint it and allow the painting to cure. This process takes a significant amount of time and therefore the system needs to be able to function without the tank in service for multiple days and in some cases several weeks. Standards for steel tanks are included in AWWA D100.

Elevated Tanks

Elevated tanks are almost always constructed using welded steel. this is only material compatible with this type of construction. In general, the storage tank component is

constructed on the ground typically in two pieces and then lifted onto the supports that are constructed separately. In some instances, elevated tanks are considered composite tanks because they include portion of the base being constructed with concrete and the remainder of the structure being built with welded steel.

Covers

All potable water storage tanks must be covered to prevent contamination by dust, birds, leaves, and insects. These covers should be watertight at all locations except vent openings. For concrete tanks, it is common to simply include a concrete cover. For elevated tanks, the top of the tank is an integral part of the structural components and is steel, the same as the rest of the tank. For steel ground storage tanks, there are two common options. With most welded tanks and some bolted tanks, the cover for the tank is also steel. However, for some steel ground storage tanks, an aluminum cover meeting AWWA Standard D108 is provided. The aluminum cover is lighter and requires substantially less maintenance since it doesn't need a protective coating.

Coatings and Corrosion

To protect the tank material, it is typically necessary to provide a coating on both the interior and exterior of the tank. Coatings for steel water tanks are covered in AWWA Standards D102 and D013. AWWA D102 describes coating systems for coating and recoating the inside and outside surfaces of steel tanks used for potable water storage. AWWA D103 provides minimum requirements for the design, construction, inspection and testing of new cylindrical, factory-coated, bolted carbon steel tanks for the storage of water. This standard is only applicable to tanks with a base elevation essentially at ground level. Coatings for the interior of concrete tanks must be NSF (National Sanitation Foundation) approved. Coatings for the exterior of concrete tanks should provide substantial protection against weathering.

SIZING CRITERIA

Regulatory Requirements

Many states have adopted the Ten State Standards for Water Works (Reference 1). These standards recommend that storage facilities have sufficient capacity to meet domestic demands and where fire protection is provided, also meet fire flow demands. Note that these are only recommendations and not regulatory requirements.

Not all storage tanks need to be provided with capacity for fire protection. In some instances, storage for fire protection can be provided by other tanks within that pressure zone or other tanks in other pressure zones. In small communities providing fire storage in the storage tank is very expensive, especially if it's an elevated tank. The other challenge with providing storage for Fire Protection is water age. In a tank that serves that has a small service area, whether that is the entire small community or a small portion of the larger community, fire storage can represent a large percentage of the required capacity. In that situation it's very difficult to get adequate mixing and turnover in the tank because daily use is much smaller than the volume of the tank.

Sizing approach based on operational requirements

Another approach to sizing required storage volume uses a total storage equal to 65% of the maximum day demand plus fire flow demands. This 65% is based on 15% for equalization storage to allow for fluctuations throughout the day and 50% for emergency use when there is some type of failure within the distribution system. These percentages can be adjusted by each community to provide for more efficient operation of a particular water distribution system.

These guidelines represent a good starting point for sizing system storage but may not be the final answer. In order to evaluate how different storage components work in a particular system, better answers are obtained by using an extended period simulation model that includes the diurnal demands of the system along with the operational controls of the supply and the operational controls for any control valves within the system.

Water systems that have multiple pressure zones may not need the entire storage capacity in every zone. Storage for fire flows or even for operational considerations can be provided in a pressure zone at a higher elevation and connected to the distribution system of the lower elevation zone through use of a pressure reducing valve or other control valve components. Storage can also be provided you know pressure zone at a lower elevation and connected to the distribution system of the higher elevation zone through use of booster pumps. Evaluation of the function of this type of system should always be verified through use of an extended period simulation model.

Fire Flow Requirements

Fire flow requirements are generally specified at a specific flow rate for a specific time period. For example, fire flow requirement might be 1000 gallons per minute for one hour, which is fairly common for single family residential areas, or a total of 60,000 gallons. The range of fire flow requirements for a distribution system is generally about 1000 gallons per minute to 3750 gallons per minute for a duration of one to three hours, depending on the size of buildings in the pressure zone and the type of construction of the larger buildings. This results in a volume of 60,000 gallons to 675,000 gallons. Commercial buildings in schools generally have relatively high fire flow requirements. These flows can be well in excess of 4000 gallons per minute.

State regulatory agencies generally do not dictate required fire flow. These requirements are usually done at the local level if they are done at all. Building codes often define required fire flows for a building but the building codes do not require a municipality to meet these requirements. Many municipalities define the maximum fire flows that the system will provide

and require individual building owners to design the buildings and fire suppression systems within the limits of the available flow.

Sizing Examples

Example 1 Criteria:

Population = 10,000

Average demand (ADD) = 100 gallons per capita per day (gpcd) = 1.0 million gallons per day (MGD)

Maximum day demand (MDD) = $2.5 * \text{ADD} = 2.5 \text{ MGD}$

Maximum fire flow requirement (one building) = school with a fire flow requirement of 3750 gpm for 3 hours = 0.675 MGD

Minimum Storage, based on 10 State Standards = $1.0 + 0.675 = 1.675 \text{ MG}$

Minimum Storage, based on operational requirements = $65\% \text{ MDD} + \text{Fire} = 0.65 * 2.5 + 0.675 = 2.3 \text{ MG}$.

Using the requirements in 10 State Standards results in a storage requirement of 1.675 MG while using the operational requirements results in a storage requirement of 2.3 MG, or about 37% more storage.

Example 2 Criteria:

Same as Example 1, except the system has two pressure zones. The higher zone has a population of 1000 and is all residential.

ADD = 100 gpcd = 1.0 MG total, 0.1 MG in higher zone

MDD = $2.5 \text{ ADD} = 2.5 \text{ MG total}$, 0.25 MGD in higher zone

Fire flow in lower zone – school requirements of 0.675 MG

Fire flow in higher zone – residential area with 1000 gpm for 1 hour requirement = 0.06 MG

Minimum storage in higher zone, based on 10 State Standards = $0.1 + 0.06 = 0.16 \text{ MG}$

Minimum storage in higher zone, based on operational requirements = $0.65 * 0.25 + 0.06 = 0.22 \text{ MG}$

Using the requirements in 10 State Standards results in a storage requirement of 0.16 MG in the lower zone while using the operational requirements results in a storage requirement of 0.22 MG, or about 37% more storage. The total storage requirements remain 2.3 MG based on operational requirements. This requirement can be met with a single 2.3 MG tank in the higher zone, but this requires pumping all of the water to the highest zone. Alternatively, it

can be met with two tanks, a 0.22 MG tank in the higher zone and a 2.08 MG tank in the lower zone.

Example 3 Criteria:

Same as Example 2, except the school is in the higher zone.

ADD = 100 gpcd = 1.0 MG total, 0.1 MG in higher zone

MDD = 2.5 ADD = 2.5 MG total, 0.25 MGD in higher zone

Fire flow in lower zone – residential area with 1000 gpm for 1 hour requirement = 0.06 MG

Fire flow in higher zone – school requirements of 0.675 MG

Minimum storage in higher zone, based on 10 State Standards = $0.1 + 0.675 = 0.775$ MG

Minimum storage in higher zone, based on operational requirements = $0.65 * 0.25 + 0.675 = 0.84$ MG

Using the requirements in 10 State Standards results in a storage requirement of 0.775 MG in the lower zone while using the operational requirements results in a storage requirement of 0.84 MG, or about 8% more storage. The total storage requirements remain 2.3 MG based on operational requirements. This requirement can be met with a single 2.3 MG tank in the higher zone, but this requires pumping all of the water to the highest zone.

Alternatively, it can be met with two tanks, a 0.84 MG tank in the higher zone and a 1.46 MG tank in the lower zone.

As an alternate to a large tank in a zone with low demand the tank can be sized for normal demand and fire pumps can be provided in the booster pump station. One of the challenges with this configuration is that the fire pumps rarely used but when they are needed it's in regulation so fire pumps are not always as reliable as we might anticipate.

Height of Tanks and Controls

The height of a storage tank is a function of the site topography, the elevations of the distribution system and the desired minimum and maximum water pressures within the system. Ten State Standards recommends a pressure range of 60 to 80 psi and requires a minimum pressure of 35 psi under normal working conditions (such as peak instantaneous flow). It also requires a minimum pressure of 20 psi under fire flow conditions.

In areas of relatively flat terrain, maintaining a pressure of 40 to 60 psi throughout the system is relatively easy to achieve, provided the distribution system has adequate pipe sizes. In areas of hilly terrain, the tank is often set to provide a minimum of 40 psi at the highest point in the distribution system, during peak flow conditions. Depending on the overall difference in elevation in the system, in systems with large elevation differences it is

not uncommon for the low areas of the distribution system to have pressures between 100 psi and 120 psi. Where pressures get too high, pressure reducing valves can be used within the distribution system to provide more acceptable pressures.

The water level in a storage tank needs to be controlled to insure the tank does not overflow, and discharge water through an overflow pipe. This is commonly accomplished through installation of an altitude valve in a vault adjacent to the tank. An altitude valve is a special type of pressure reducing valve that closes when the downstream pressure reaches a preset level. In the case of the altitude valve, the preset pressure is the full level of the tank. An altitude valve is much more sensitive than a standard pressure reducing valve and can be set very accurately. If a pressure reducing valve is used, it is typically accurate only to ± 1 or 2 psi, which is 2 to 5 feet. Having the water level in the tank 3 or 4 feet too high results in significant overflow and loss of water.

In lieu of the use of an altitude valve, it may be desirable to have a control valve installed that receives a signal from a level monitor in the tank. When the level in the tank reaches the desired fill level, this monitor signals for the control valve to close. When the hydraulic head on the distribution system side of the tank drops below the hydraulic head in the tank, the monitor signals for the control valve to re-open.

Overflow Pipes

Another requirement in Ten State Standards for storage tanks is an overflow. There is always the potential the level controls for a tank will fail and water will continue to enter the tank after it is full. Therefore an overflow pipe is required. There are a number of requirements for an overflow pipe in Ten State Standards, including:

1. All water storage structures shall be provided with an overflow which is brought down to an elevation between 12 and 24 inches above the ground surface, and discharges over a drainage inlet structure or a splash plate. No overflow may be connected directly to any drain, sanitary sewer or storm sewer. All overflow pipes shall be located so that any discharge is visible.
2. When an internal overflow pipe is used on elevated tanks, it should be located in the access tube. For vertical drops on other types of storage facilities, the overflow pipe should be located on the outside of the structure.
3. The overflow shall open downward and be screened with twenty-four mesh non-corrodible screen. The screen shall be installed within the overflow pipe at a location least susceptible to damage by vandalism.
4. The overflow pipe shall be of sufficient diameter to permit waste of water in excess of the maximum filling rate. This sounds like a simple requirement but requires careful hydraulic calculations. Where the inlet pipe enters the tank is almost always a short horizontal section of pipe. This pipe will be in inlet control and therefore the vertical section of the pipe has essentially no impact on the capacity of the pipe. The capacity is entirely controlled by the size of the inlet pipe and the depth of water over the inlet pipe. In order to control the depth of water in the tank and limit the size of the overflow pipe, a weir box is often constructed inside the tank. The top of this weir box

is set at the maximum desired water level. The length of the weir is relatively large so only a small depth of water above the weir (usually less than one foot) is necessary to discharge the maximum flow. The invert of the pipe can be set inside the weir box, below the high water level, so adequate head can be reached without exceeding the allowable high water level.

Foundation Requirements

Storage tanks require a substantial foundation. This is the case whether the tank is constructed of concrete, which is a relatively heavy material, or steel, which is a much lighter material. Most of the load on the foundation of a ground storage tank is a result of the weight of the water inside the tank, not the weight of the tank itself. It is very important in the design of a storage tank to get a good geotechnical investigation of the soils below the tank. The foundation design is sometimes left to the tank manufacturer, but it must the responsibility for the foundation must be appropriately addressed in the overall design.

FLUCTUATIONS IN WATER LEVEL

One of the challenges of sizing water storage tanks is to allow the water level to fluctuate while still providing adequate storage. This fluctuation is usually necessary to provide adequate mixing in the storage tank so that the water quality in the tank is maintained. One of the ways to evaluate the mixing in a storage tank is to look at a graph of the fluctuation in water.

Figure 9 shows an example graph of the water level fluctuation over a two-day time period in the smaller elevated tank in Example 3. This figure shows the water level in the tank starting at about 80% then dropping down to about 65% then fluctuating between 65% and 75% over the next 36 hours. Figure 10 shows an example graph of the pump operation for this same scenario. The pump controls are set to start when the tank level drops to 65% which occurs at about hour 11 in this graph. The pump then continues to operate continuously throughout the remaining time period with the flow fluctuating only due to changes in the demand. These two graphs provide a good visual representation of the flow scenario based on the controls in the model.

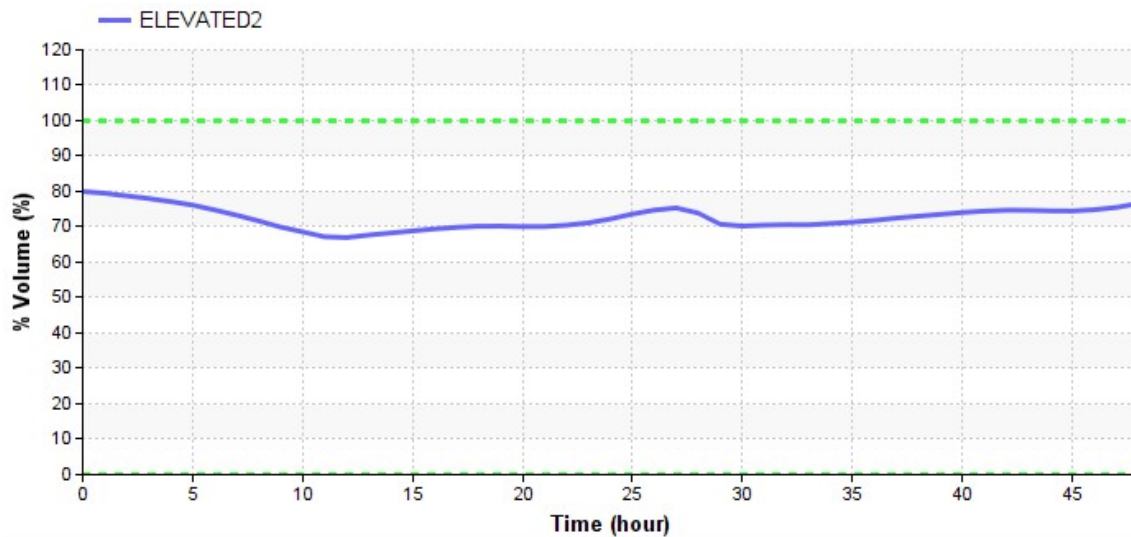


Figure 9

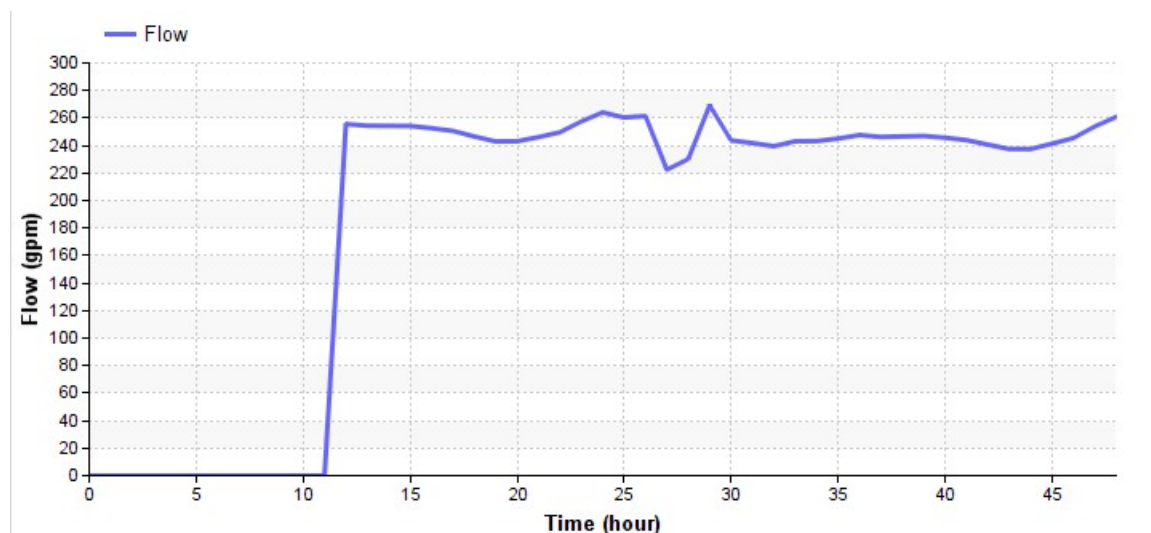


Figure 10

Figure 11 shows an example graph of the water level fluctuation over a two-day time period in the larger tank in Example 3. This figure shows the water level in the tank starting at about 55% then increasing to about 90%, the fluctuating between 60% and 95% for the next 36 hours. Figure 12 shows an example graph of the pump operation for this same scenario. The pump runs until the tank level reaches about 95% full, then turns off for several hours, before re-starting. The pump then continues to operate continuously throughout the remaining time period with the flow fluctuating only due to changes in the demand.

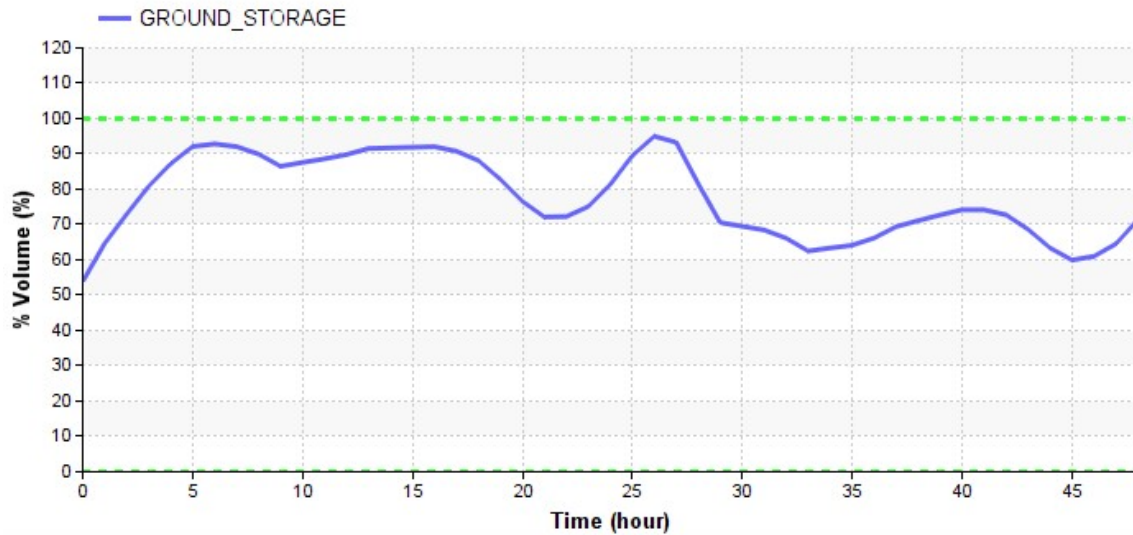


Figure 11

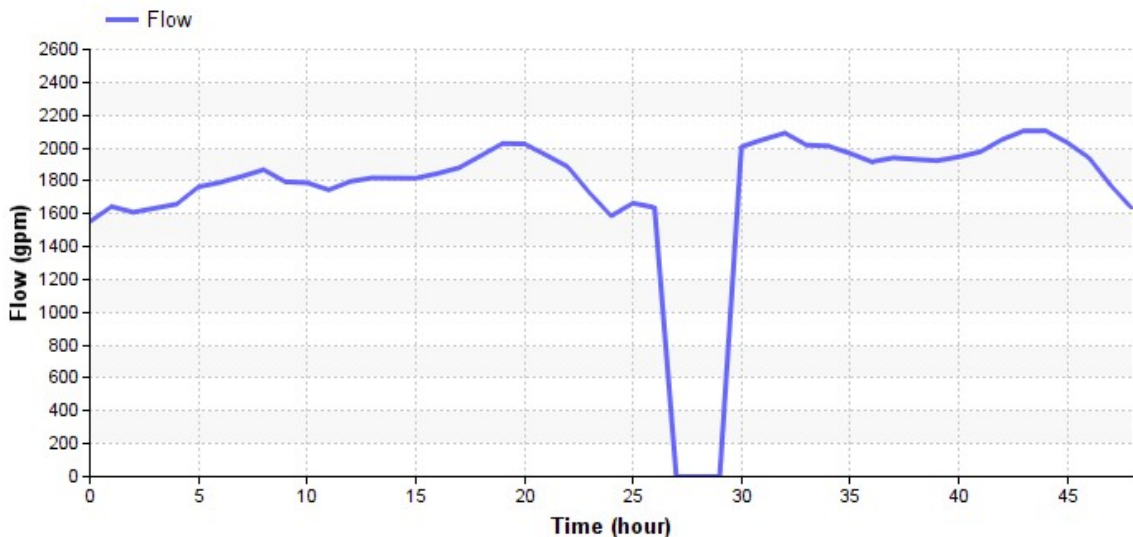


Figure 12

The demands on a water system in the winter are often much lower than demands in the summer. This is because many systems provide a substantial amount of water for irrigation, especially for residential lawns. The demand in the summer can be two to three times the average day demand and as much as four times the minimum day demand.

In systems where the storage requirements are largely driven by demand, rather than emergency storage or fire flow storage, significantly less storage is required in the winter. This can be accomplished by modifying the set points for the pumps that deliver water to the tank, which will result in a lower water level in the tank during the winter. The lower demand also results in less water coming into the tank each day. In colder climates, this can result in

formation of substantial ice inside the tank, which can damage the tank itself or the coatings on the inside of the tank.

WATER AGE AND MIXING

Looking at water age from a very simplistic viewpoint, the water age in days is equal to the total storage volume divided by the daily demand. For example, for a storage tank with a capacity of 1.0 million gallons and a demand of 500,000 gallons per day, the water age is 2 days. In general, though, water in storage tanks tend to be poorly mixed. The water near the intake/discharge pipe is turned over frequently, but the water near the edges of the tank and at the top tends to stagnate. This stagnant water can result in taste and odor issues and also lose all of the chlorine residual and no longer be potable.

Thermal Impacts

There are several thermal impacts that occur in a storage tank. The temperature of the water coming into the tank could vary only slightly if the source of the water is groundwater. If the source of the water is surface water, the temperature is likely to vary much more substantially. In either case, the temperature of the water coming into the tank will be different than the temperature of the water already in the tank (see Figure 13).

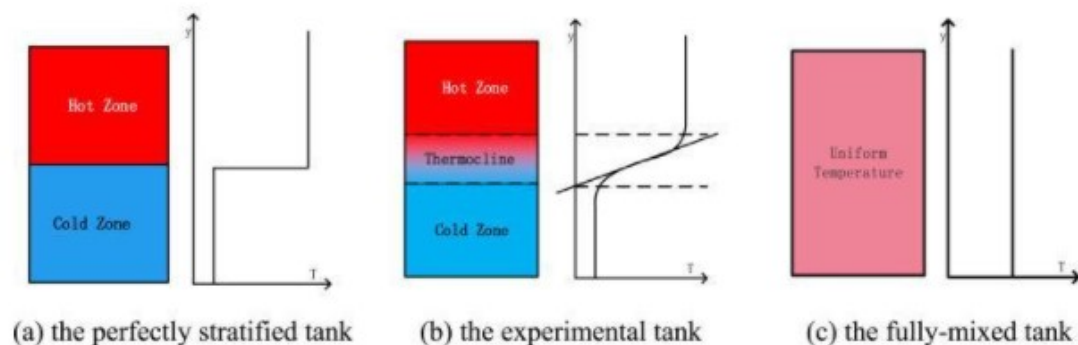


Figure 13 – Thermal Stratification (courtesy of Kasco Marine, Inc. copyright 2021)

During the winter, the water in the tank could be near freezing, especially in northern climates. The incoming water will be warmer and therefore bring heat into the tank to raise the overall temperature of the water in the tank. However, water demand is usually lower in the winter therefore the amount of heat coming into the tank is related to the average day or minimum day demand, rather than the peak day demand. For tanks that have significant fire flow storage, even the average day demand may not bring a substantial amount of heat into the tank. These types of tanks are much more susceptible to extreme ice.

In general, ice builds up on the sides of the tank. The sides of the tank are exposed to the cold atmosphere and both concrete and steel transmit these cold temperatures effectively to the water on the inside of the tank. There are two potential solutions to tanks where ice becomes problematic. The first solution is to provide improved mixing in the tank. This will distribute the heat coming into the tank more evenly which will reduce the potential for ice formation. However, in very cold climates and in tanks with low turnover, this may not be sufficient. In this case, it may be necessary to add a tank heater. The heater is typically placed on the bottom of the tank and serves two purposes. It obviously raises the temperature of the water adjacent to the heater, but because warm water is less dense than cold water, the warmer water rises to the top of the tank, increasing overall mixing in the tank.

Mixing

The difference in density between cold water and warm water creates thermal stratification in a tank. This thermal stratification inhibits the normal mixing process, accelerates the loss of disinfectant residual and creates inconsistent water age. Adequate mixing is often considered to be a problem only in the winter, when flows into and out of the tank are smaller. However, short circuiting within the tank tends to be a definite issue, especially in the summer. When cold water comes into the tank during the summer, it is usually colder than the water in the tank. Therefore, the incoming water tends to stay at or near the bottom, so the last water coming in can also be the first water going out. Installation of a mechanical mixer can significantly improve tank mixing and reduce the overall water age in the tank (see Figures 14 and 15). The mixer can be either a floor mount (see Figure 14) or hang in the tank (see Figure 15). These mixers can be powered either by a standard electrical connection or through the use of solar power. A solar powered mixer is sometimes the best choice when the tank is at a remote location where electrical power is not readily available.

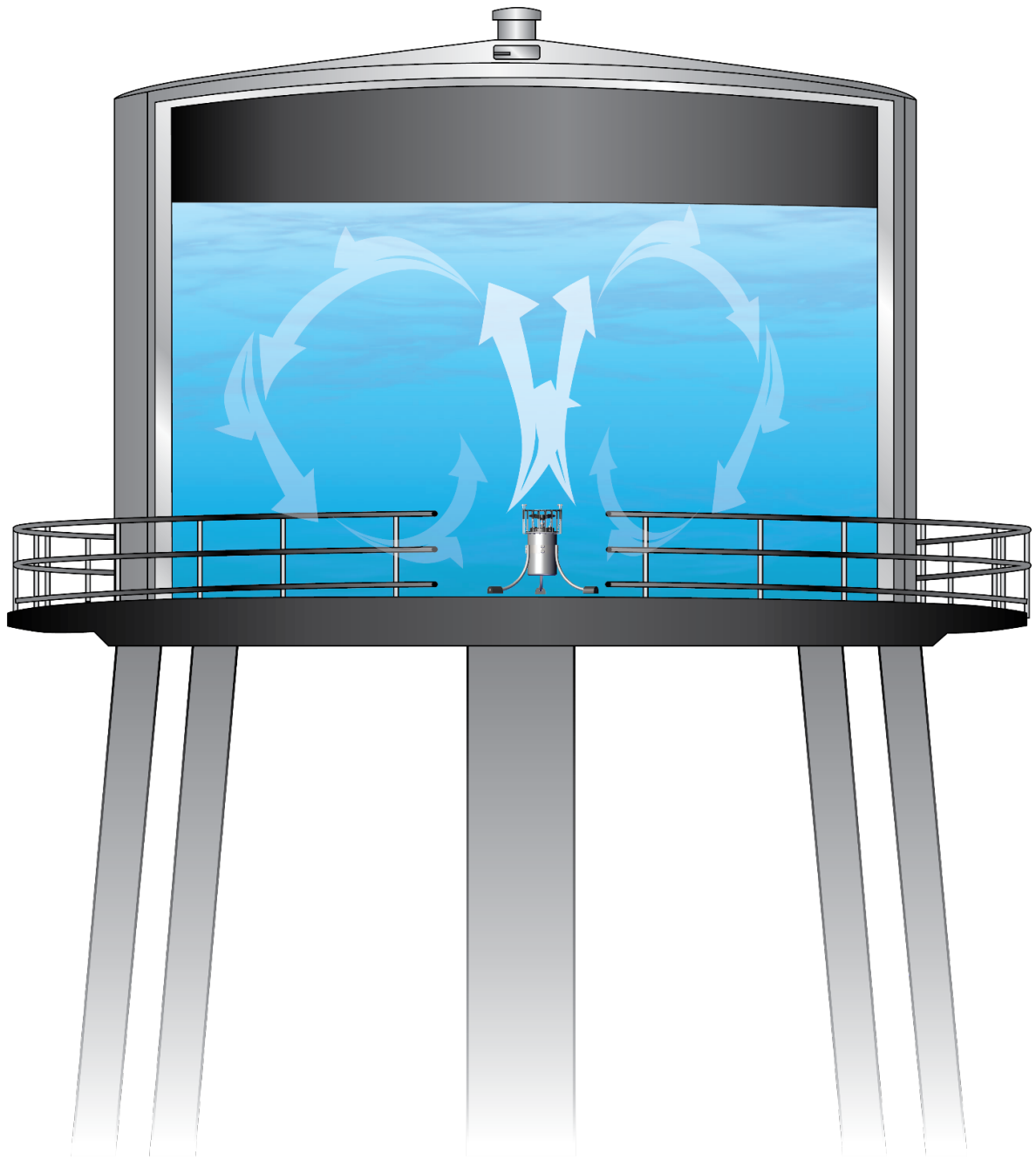


Figure 14 (courtesy of Kasco Marine, Inc. copyright 2021)

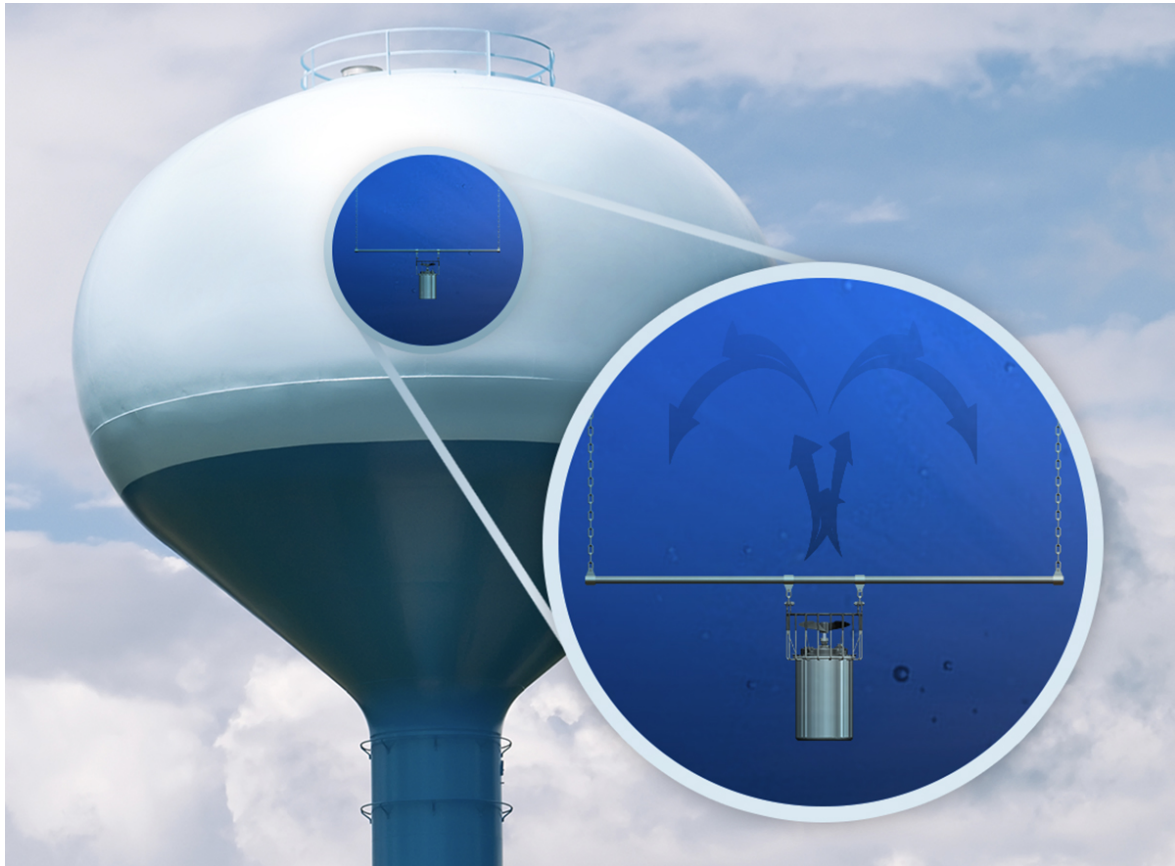


Figure 15 (courtesy of Kasco Marine, Inc. copyright 2021)

INLET AND OUTLET PIPING

For many tanks, there is only one pipe that enters the tank. This pipe serves as an inlet to the tank when system pressure is greater than the head in the tank and serves as an outlet to the tank when system pressure is lower than the head in the tank. While this is a common design, other options can provide significantly improved mixing and water quality in the tank.

One way passive mixing in the tank can be improved is through the use of separate inlet and outlet pipes. One approach to this design is shown in Figure 16. In this schematic, the water enters the tank from the left and exits the pipe on the right. This configuration significantly improves the natural mixing action inside the tank. In addition to the separate inlet and outlet, Figure 16 also shows the inlet pipe discharging into the tank at an elevation significantly higher than the base of the tank. With this configuration, the top of the inlet pipe shouldn't be set at the highest water elevation in the tank, but rather at some intermediate elevation so under normal flow conditions the inlet is still submerged even when the water

level is drawn down. This higher inlet pipe can significantly decrease the problems associated with thermal stratification, both in the summer and the winter.

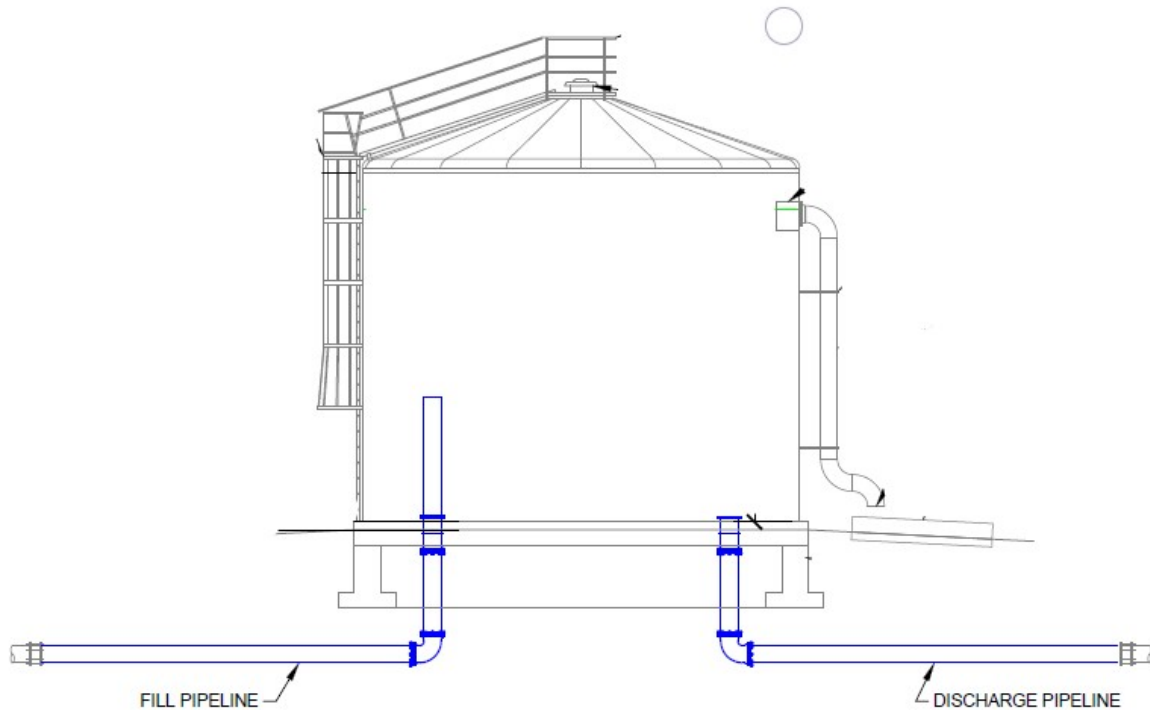


Figure 16 – Tank Fill and Discharge Piping

The most effective way to incorporate separate inlet and outlet pipes is if there is a dedicated pipe from the supply to the tank inlet and a dedicated pipe from the tank outlet to the distribution system. However, there are many tank locations where this option is not available. However, even when this option is not available, it is still possible to install separate inlet and outlet pipes and obtain most of the advantages of the mixing associated with this configuration. This will require a small amount of additional piping in a vault adjacent to the tank. Figure 17 shows an example schematic for a single transmission line to the tank. Valves 1 and 2 in this schematic are control valves that open or close based on tank level. Valve 3 is a standard gate valve. The operation of this tank is controlled as follows:

1. Control Valve 1 is open when the water level in the tank is “low” and the system is filling. This valve closes when the tank reaches the full level.
2. Control Valve 2 is closed during the filling operation. When the tank reaches the full level and Control Valve 1 closes, then Control Valve 2 will open. This allows water from the tank to feed the distribution system.
3. Valve 3 can be closed to allow maintenance on the tank.

The interior piping for the tank would be similar to Figure 16. This allows for a separate inlet and outlet piping that functions essentially the same as a tank with an inlet from the supply and an outlet to the distribution system without the need for completely separate piping.

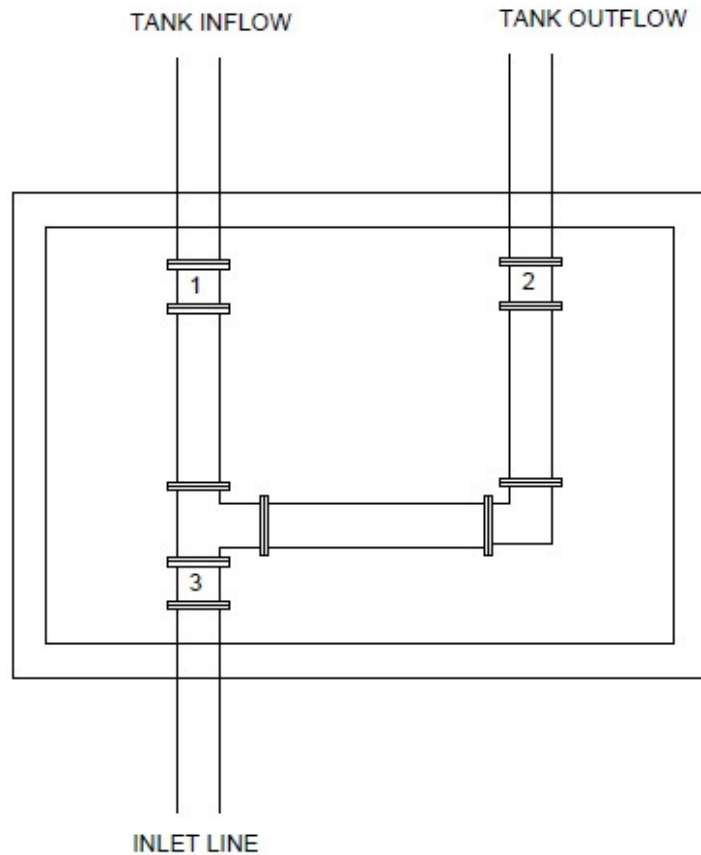


Figure 17 – Tank Piping Option

REFERENCE

1. "Recommended Standards for Water Works", Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers.

Designing Storage Tanks for Water Distribution Systems - Quiz

Updated: 4/25/2022

1. A standpipe is a special case of which type of tank?
 - a. Ground storage tank
 - b. Elevated tank
 - c. Either of the above
 - d. None of the above
2. What is the most common material used for elevated tanks?
 - a. Steel
 - b. Concrete
 - c. PVC
 - d. HDPE
3. Very large storage tanks are almost always which type of tank?
 - a. Elevated Tanks
 - b. Ground Storage Tanks
 - c. Standpipes
 - d. None of the above
4. Access for maintenance is a more challenging issue for which type of tank?
 - a. Ground storage tank
 - b. Standpipes
 - c. Elevated tanks
 - d. They are all the same.
5. How are sections of a steel tank connected together?
 - a. Welded
 - b. Bolted
 - c. Both of the above
 - d. None of the above
6. Which of the following AWWA Standards covers concrete tanks?
 - a. D100
 - b. D102
 - c. D103
 - d. D110
7. What is the regulatory requirement for the amount of storage for fire flow?
 - a. 1000 gallons a minute for one hour, or 60,000 gallons
 - b. 2000 gallons a minute for two hours, or 240,000 gallons
 - c. 3750 gallons a minute for three hours, or 675,000 gallons
 - d. It depends on the size of buildings and the type of construction

8. What is the minimum required storage volume, based on Ten State Standards, for a system with an average day demand of 1 MGD, a maximum day demand of 2.5 MGD, and a fire flow demand of 0.675 MGD?
- a. 1.0 million gallons
 - b. 1.675 million gallons
 - c. 2.5 million gallons
 - d. 3.175 million gallons
9. When there are multiple pressure zones, what is the required location of the storage tank?
- a. All storage must be in the zone with the highest elevation
 - b. All storage must be in the zone with the lowest elevation
 - c. Storage can be split between the zones, provided the individual storage requirements for each zone are met.
 - d. None of the above.
10. What is the minimum allow pressure in the distribution system under normal working conditions, based on Ten State Standards?
- a. 20 psi
 - b. 35 psi
 - c. 60 psi
 - d. 100 psi
11. An overflow pipe will typically include which of the following components:
- a. A pipe
 - b. A screen
 - c. A weir box
 - d. All of the above
12. During what season are water demands typically the highest?
- a. Spring
 - b. Summer
 - c. Fall
 - d. Winter
13. Which of the following impacts the real water age in a storage tank?
- a. Tank volume
 - b. Daily demand
 - c. Effectiveness of mixing
 - d. All of the above
 - e. A and B only

14. Colder water in the tank will typically be in what part of the tank
- a. Near the top
 - b. Near the bottom
 - c. In the middle
 - d. Uniformly distributed throughout the tank
15. Which of the following configurations promotes the most passive mixing in a tank?
- a. A single pipe for inlet and outlet, at the bottom of the tank
 - b. Separate pipes for inlet and outlet, at the bottom of the tank
 - c. Separate pipes for inlet and outlet, with the outlet pipe at the bottom of the tank and the inlet pipe extended up into the tank.
 - d. None of these configurations promote passive mixing.