

Storage

Vessels or tanks for storing potable water are critical to the efficient operation of any water distribution system. Storage tanks serve two major purposes. One is to provide storage volume and the other is to provide pressure to the distribution system. A particular tank can serve one or both purposes depending on its location within the system and its type of configuration.

There are a variety of tank types or configurations. The major types are ground storage, elevated, and hydropneumatic tanks. Construction materials for the various types of tanks are generally concrete and steel although some tanks for small storage volumes and special uses could be constructed of fiberglass. The operation of storage tanks is critical to maintaining a continued flow of water to a distribution system for domestic, commercial, or industrial use and for fire protection. The sizing of a water storage tank is dependent upon the function it is intended to provide. Each water distribution system is unique in its need for storage. Other factors, such as cost, also play an important role in determining the size of a potable water storage tank. The maintenance of storage tanks is critical to public health and safety. A water storage tank should be inspected, cleaned, and repaired regularly to be considered reliable.

TANK PURPOSES

The two primary purposes for the use of storage tanks within a water distribution system are to provide storage and pressure. Many water storage tanks provide both.

Providing sufficient storage volume is generally the function of a water storage tank. A typical operating day in any public water system involves varying demands for the water. The demand volumes that a system may use for planning design purposes are:

AVERAGE DAY DEMAND in million gallons per day (MGD):

The total amount of water use for a system for a year divided by 365 days.

AVERAGE WINTER DAY DEMAND in MGD:

The total amount of water use for a system during the months of December, January, and February, divided by the number of days in the period (either 90 or 91 depending on whether February has 28 or 29 days).

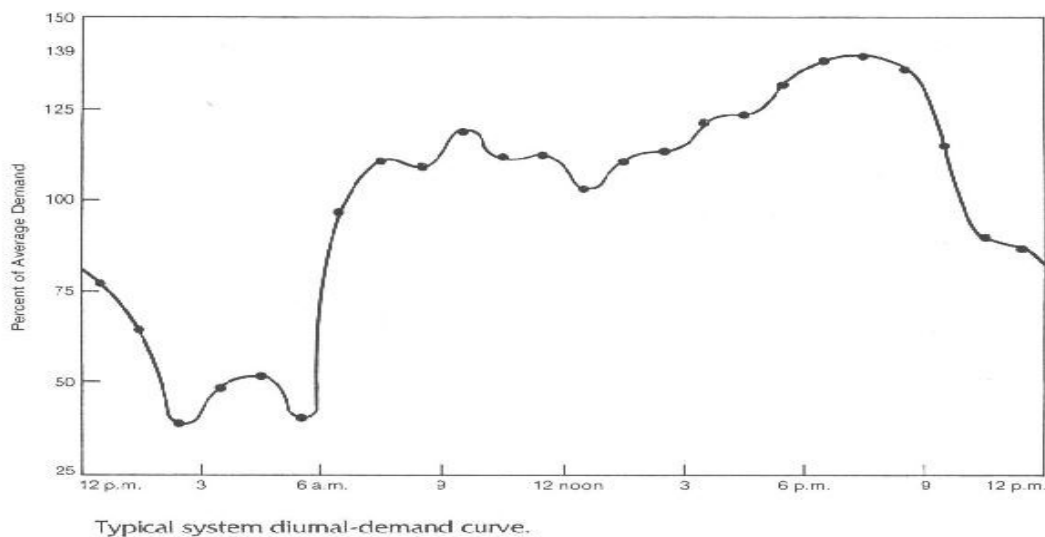
AVERAGE SUMMER DAY DEMAND in MGD:

The total amount of water use for a system during the months of July and August, divided by the number of days (62).

PEAK DAY DEMAND in MGD:

The highest daily water use for a system in one 24-hour period. It is generally best to take the average of the peak-day demand over a period of several years. This smooths out averages that could be abnormally high because of a situation that could have caused excessive demand on one of the days.

It is not necessary to have pumps capable of supplying a system with water to accommodate all of the varied demand conditions. The reason is illustrated by showing the hourly variations of water demands during a 24-hour period for a typical system.



A storage tank allows the use of constant flow in the distribution system. Pumps that fill the storage tanks are operated by controls which start and stop them as the water level in the storage tanks rises and falls during the day. When demands are high, the pumps cannot keep up with the requirements for the water and the storage volume is reduced. When demands are low, the pumps have excess capacity and are able to refill the storage tank to full for the next high-demand period.

The other function of storage tanks is to provide pressure. All water distribution systems must have a means of pressurizing the system. The most common method of creating system pressure is through the use of an elevated water storage tank to develop the necessary feet of head to force water through the system.

If the land around the distribution systems allows, a ground-storage tank can be constructed on a high hill to serve as an elevated storage tank.

Another method of pressurizing water distribution systems is through the use of hydropneumatic tanks although they usually provide very small amount of reserve storage and are not adequate for fire-protection purposes.

TYPES OF WATER STORAGE TANKS

There are three basic types of potable water-storage tanks: ground storage tanks, elevated storage tanks, and hydropneumatic tanks.

Ground storage tanks can be installed either below or above ground. They are fabricated of concrete or steel. They generally have the function of providing large volumes of storage for peak-day demand when the capacity of the source of supply is less than the maximum daily volume the specific system may need. An example of a situation in which the peak-day demand is larger than what the system can deliver daily is a system served by a well that can deliver only enough water to satisfy the distribution system for a short time of high-volume need. Having a large ground storage tank allows the operator to set the pumps to operate mainly during off-peak hours, usually overnight when power rates are lower, to fill the tank for the daytime peak period demand.

It is usually necessary to pump water from a ground storage tank to an elevated storage tank to provide uniform pressure to a distribution system. Ground storage tanks can provide system pressure if they are located on hills within or near the distribution system area. Such situations are ideal since ground storage tanks are usually less expensive to construct than elevated storage tanks.

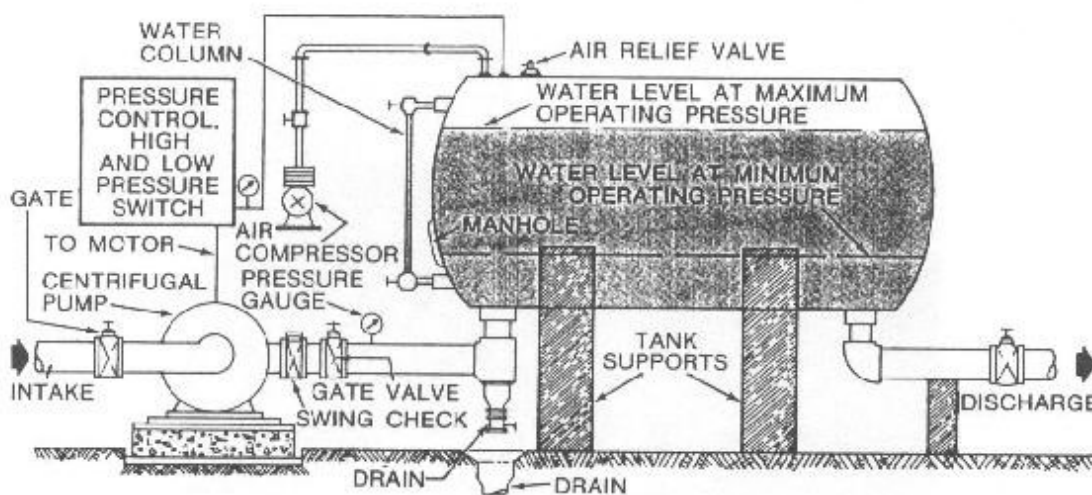


A Ground Storage Tank

Ground storage tanks constructed of concrete can be built either below or above ground. Concrete is used more often for below-ground construction because it is not affected by corrosion and has the strength to support the pressure of the earth around it even when empty. Older below-ground tanks made of concrete were constructed with a covering of earth over the top to protect the tank and provide insulation. This is no longer acceptable because of concerns of leaks in the roof or hatches which could allow rain or groundwater to enter the tank with chemical or biological contaminations such as fertilizer, herbicides, pesticides, and pathogenic bacteria or viruses. Current standards require that the top or roof of a below-ground potable water storage tank be constructed at a height of not less than two feet above the surrounding grade. Concrete used for above ground-storage tanks is usually pre-cast and assembled at the site, in a circular shape to provide strength.

Because of the relatively low construction cost, above-ground tanks constructed at ground level are usually made of either welded or bolted steel. Following construction, welded steel tanks must be coated both inside and out to protect against corrosion and electrolytic reactions which eventually could cause leaks or structural damage. Bolted steel tanks are usually lined with a factory-applied glass coating, and seams are caulked during construction to prevent leaks.

Hydropneumatic tanks are used to provide pressure to very small public water systems such as resorts, mobile home parks and very small communities. They are not a good storage vessel for fire protection purposes due to the small volume of water within the vessel.



Pneumatic Steel Pressure Tank

Hydropneumatic tanks operate on the same principle as a home water system in that the pressure-rated tank contains approximately two-thirds water and one-third air at full capacity. An air compressor is required to maintain a proper volume of air within the tank at the necessary pressure. At low operating level the tank will contain about one-third water and two-thirds air.

The air is pressurized to provide a system head and operates at about a 20-pound-per-square-inch pressure difference between high and low water levels. A system using a hydropneumatic tank with a need for an average operating pressure of 40 pounds per square inch (psi) would then have a 50 psi pressure at high levels and a 30 psi pressure at low levels.

Hydropneumatic tanks are generally constructed of steel and must meet the standards of the American Society of Mechanical Engineers (ASME) for pressure-rated tanks. The tanks are usually long and cylindrical, positioned horizontally on concrete support piers. They look similar to a propane storage tank.

Hydropneumatic tanks must be housed in a heated building to prevent freezing of the tank and associated piping, air compressor, and controls.

Elevated storage tanks are usually constructed of welded, bolted, or riveted steel, although a few wooden tanks still exist. Configurations for elevated steel tanks include standpipes, leg or supported tanks, and single pedestal tanks.



Standpipes are essentially ground storage tanks constructed to a height that will provide adequate system pressure in the operating range. Their diameter is constant from the ground to the top, and they are completely filled with water. While a standpipe contains a large volume of water, only the upper volumes would be available for use if pressure demands throughout the system are to be maintained. There is a tendency for lower-level standpipes to freeze unless they are operated very carefully or equipped with circulation or air bubblers to prevent or reduce ice build-up in the winter. Standpipes are generally constructed of welded or bolted steel. Access to the top of the tank is usually by an exterior ladder. The inlet pipe generally only extends one to two feet above the floor at the base.

Leg supported tanks are the most common type of elevated tank seen in our area. A large volume tank is supported by a structural system of legs and crosses or wind bracing. Water enters and leaves the tank through an insulated riser pipe usually located in the center of the support structure for the tank. This type of elevated tank is less prone to freezing than a standpipe because the water tends to circulate better throughout the stored volume. Leg supported tanks still require careful operation to minimize ice sheet build up during the winter months.





Single pedestal tanks have a single support structure in the center of the tank with a large volume tank at the top. A pedestal tank is easier and less expensive to maintain, but more costly to construct. The riser pipe and access ladder are contained within the pedestal tube and, since the pedestal and base are not normally heated, the riser pipe is insulated to reduce the potential for freezing.



There are many variations of each of these three types of elevated water storage tanks. In all cases, however, the system pressure is provided by the height of the water above the ground. This type of water storage tank is generally the most cost-effective method of maintaining a relatively uniform operating pressure within a water distribution system.

OPERATION OF STORAGE TANKS

The proper operation of a water storage tank is critical to both the overall system operation and the life of the water storage vessel. Improper operation can result in large repair and maintenance costs in addition to shortening the storage tank's useful life. It is important to reduce ice build-up within non-heated tanks and to periodically clean the interior of the tanks for health and maintenance reasons.

The operating principles of all the pressure-creating tank types are the same.

All gases, liquids, and solids have weight as a result of the Earth's gravitational forces. In order for a liquid, such as water, to create a downward force it must be contained within a vessel. Otherwise, it will simply flatten out on the surface. When dealing with liquids, the force exerted by the weight of a contained liquid is expressed in terms of the weight of the liquid over a certain area of flat surface, expressed in pounds per square inch (psi). For example, freshwater weighs 62.4 pounds per cubic foot. In other words, the pressure exerted on a one-square-foot surface that is one foot deep is 62.4 pounds per square foot (psf).

Dividing the psf by 144 (the number of square inches in one square foot) tells us that the weight per square inch exerted by a one-foot depth of water is 0.43333 (about 7/16) pounds per square inch (psi).

A cube of water one inch square and one foot high weighs 0.4333 pounds. If 100 of these pieces of water were stacked one on top of the other, the weight would be 43.33. This stack of water would exert 43.33 pounds of weight on the one-square-inch surface on the bottom or 43.33 pounds of pressure per square inch.

Water contained in a vessel or pipe 100 feet high will exert a pressure of 43.33 pounds per square inch at the bottom of the pipe. The pressure is constant no matter the diameter of the pipe. It could be one inch or ten feet in diameter, but the pressure at the bottom of this vessel will still be 43.33 pounds per square inch.

With this in mind, it becomes easier to understand that an elevated tank will create a pressure equal to its height in feet to the water line times 0.433 pounds. Pressure can also be expressed as feet of head. One foot of head equals 0.433 psi. One psi equals 2.31 feet of head.

For further practice calculating head and pressure, study the Mathematics chapter in this manual.

WINTER OPERATION

Ground storage tanks are the easiest to operate as they are readily accessible for observation. The most important concerns are ice build-up and damage to the coatings and the structure. Below-ground tanks are less prone to ice build-up than above-ground tanks. During warm-weather months, coating life can be extended by operating at fuller levels. This reduces the temperature changes and subsequent expansions and contractions of the tank which can damage the coating materials.

Ground storage tanks with the single purpose of providing reserve storage should be kept full to avoid stagnant water and ensure minimal ice formation. Hatches to water storage tanks should be locked at all times to ensure security of the tanks from vandalism.

The major concern during a severe winter is for damage to the interior of a ground storage tank by abrasion to the coating. As a floating sheet of ice moves up and down with the water level, the sides of the tank are rubbed and the life of the coating is shortened. The second concern is for damage to the tank itself. Ice creates tremendous pressure as it freezes and thaws. If allowed to occur, these pressures can bend or break the tank. The third concern is the fact that storage volume of the tank is reduced by the volume of the ice in the tank. Overflow systems on ground storage tanks should be checked frequently for ice build-up. The bug screens on the overflow vent should be checked often.

Elevated tanks are very prone to ice formation because they are entirely exposed to the elements. Wind and cold quickly dissipate or remove the heat from the water in the tank. If possible, an elevated tank should be operated with at least one volume change per day. This will reduce the formation of stagnant water as well as ice. Overflow systems should be checked frequently. Any ice formation from an accidental overflow should be removed to prevent structural damage. Ice on the tank adds weight to the structure. This additional weight, which was not considered in the design of the tank, can cause severe damage. Under extreme conditions, the tank could even collapse. Elevated tanks should also be locked to prevent vandalism. This reduces the liability of the owner.

Hydropneumatic tanks are not prone to freezing and ice formation as they are usually housed in heated buildings. These tanks should never be operated above the pressure rating of the tank shown on the manufacturer's plate. The pressure blow-off valve should be checked frequently for proper operation. This tank, like any of the others, requires regular cleaning and inspection of the interior.



ROUTINE MAINTENANCE

The routine maintenance includes mowing the area around the tank foundation, sweeping debris from the foundations, checking the locks on hatches, observing the pressure gauges within the system, and, during the winter months, periodically comparing pumping records. Sweeping the foundation tops on a regular basis will reduce coating, base-plate, and concrete failure at the tank foundation. Utility staff should inspect the tank surface regularly, checking especially for any peeling of the coatings. This inspection should include the inside of the tank as well as the outer surface. Because of the specialized inspection-rigging equipment required, it is best to have the inside surfaces inspected by a consultant.

The comparison of pumping records and tank-water levels during winter months can help indicate if there is ice build-up. If the ice is floating, the problem will not be evident. A careful comparison can, however, warn an observant operator of ice formation clinging to the tank walls. If, for the same operating range, less water is required to fill a tank during the winter than during the summer, ice is probably attached to the tank walls. Because the ice displaces an equal volume of water at both high and low levels, floating ice can only be observed visually when a tank is operating.

VOLUME SIZING OF POTABLE WATER STORAGE TANKS

The design and sizing of a water storage tank is best performed by a consulting professional engineer. The process is quite complex and involves many considerations. The operators need to have a basic knowledge of the recommendations for storage volume within a system. The current recommendations are that the storage volume should be equal to the average daily demand for the system, not including fire protection requirements. These recommendations are sound from the standpoint of being able to provide for public water supply and fire protection for a day without having to pump water into the tank; however, because of the climate, they are often not practical in Minnesota. In most cases, because the water cannot be changed frequently, a stored volume of water for both fire protection and public use will be so large that freezing will occur. Each water system must be analyzed individually to provide for the best combination of storage volume, fire protection needs and the water use patterns of the customers to provide a storage volume which is adequate, but also manageable and affordable for the system.