STATE OF CONNECTICUT DEPARTMENT OF PUBLIC HEALTH
DRINKING WATER SECTION

STORAGE TANK DESIGN AND CONSTRUCTION GUIDELINES

Effective Date: August 8, 2006

Authority: Section 19-13-B102(d)(2) of the Regulations of Connecticut State Agencies (RCSA) requires approval from the Department of storage tanks prior to construction. The following guidance is provided in the interest of facilitating the approval process. Discretion in the application of these guidelines is allowable except as required by regulation.

Definitions

(1) Hydropneumatic tank: also commonly referred to as a pressure tank means any storage vessel that contains both water and air under pressure (i.e. not under atmospheric conditions). The compressed air in the tank imparts pressure to water stored in the tank and connected distribution piping. A standard or conventional hydropneumatic tank does not have an air-water separator, and the stored water is in direct contact with the compressed air. Conventional hydropneumatic tanks are typically cylindrical vessels installed horizontally either completely buried or more commonly partially buried with one end projecting (bulkheaded) into an operations building wall. Hydropneumatic tanks may also be equipped with an air-water separator, typically a bladder or diaphragm, and are typically completely housed and installed vertically. Hydropneumatic tanks that use a bladder as an air-water separator are typically referred to as bladder tanks.

(2) Storage tank: as used in these guidelines means any storage facility that holds finished water ready for potable consumption and is connected to a public water system (PWS). Common examples include, but not limited to, standpipes, elevated tanks, ground level, buried, and partially buried tanks and reservoirs, hydropneumatic tanks, and clearwells.

(3) Usable storage: means the volume of stored water that can be effectively utilized without causing distribution system pressures to fall below minimum required pressure levels or causing damage to pumps which take suction from the tank.

Location

(1) Section 19-13-B102(d)(1) of the RCSA requires storage tanks to be located above the level of the 100-year flood elevation. When feasible, the foundation for ground level storage tanks, standpipes, and elevated storage tanks should be located at least three feet above the 100-year flood elevation.

(2) Section 19-13-B102(f)(5)(B) of the RCSA requires in-ground finished water storage tanks to be located at least 50 feet from any part of a subsurface sewage disposal system or sanitary sewer and at least 25 feet from the nearest watercourse, storm drain, or other source of pollution. Section 19-13-B102(f)(5)(B) of the RCSA allows the 50-foot separating distance requirement for sanitary sewers to be reduced to 25 feet if the sanitary sewer is constructed in accordance with Section 19-13-B103d of the RCSA (Technical Standards for Subsurface Sewage Disposal Systems).

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Sizing

The following are intended to be general guidelines for sizing the most common types of storage tank configurations. Additional criteria specific to the public water system or other types of storage tank configurations may be required to be evaluated in order to properly size a storage tank. Section 19-13-B102(p) of the RCSA requires storage tanks to be sized to provide flows in excess of the maximum flows experienced in the water system or service zone served by the storage tanks.

(1) Atmospheric storage tanks:

(A) The following factors should be evaluated when sizing atmospheric storage tanks:

i. capacity, operational strategy, and back-up capabilities of sources of supply,
ii. source of supply pumping stations and treatment facilities,
iii. equalization storage during peak demands,
iv. fire flow storage (if fire protection is provided),
v. emergency reserve storage,
vi. future growth of the system or service area served by the storage tank,
vii. system pressures at the highest and lowest customer service elevations served by the storage tank.

The usable storage capacity should be able to satisfactorily meet of all the required demands for which the storage tank is sized. The minimum usable storage capacity for atmospheric storage tanks not providing fire protection should be equal to the average daily demand (ADD) of the PWS or service area served by the storage tank. When fire protection is to be provided, fire flow storage capacity and minimum hydrant pressures should be in accordance with the requirements of the local fire protection regulatory authority.

(B) For a small PWS that will utilize an atmospheric storage tank in conjunction with a booster/transfer pump and hydropneumatic tank system to meet demands (<u>not</u> including fire flow demands), the minimum usable atmospheric storage tank capacity should be equal to the ADD of the PWS.

(2) Hydropneumatic tanks:

(A) Hydropneumatic tanks are typically installed by small systems to maintain system pressure within a predetermined range while minimizing excessive pump cycling. Hydropneumatic tanks typically only provide very limited equalization and emergency storage and therefore should not be considered to be effective storage facilities for such purposes. Whenever possible, hydropneumatic tanks should not be a substitute for a properly sized atmospheric storage tank.

(B) When used in conjunction with booster/transfer pumps and properly sized atmospheric storage (as sized in section (1)(B) above), conventional hydropneumatic tanks <u>without</u> an air-water separator may be sized as follows:

Usable volume (gallons) = (5 minutes) X (largest booster/transfer pump capacity in gpm*)

Gross volume (gallons) = (Usable volume in gallons as calculated above) / 0.2**

*Booster/transfer pumps should be sized such that the firm capacity of the pumps is adequate to meet the peak hour demand. Booster/transfer pumps are covered in more detail in the Pumping Facilities Design and Construction Guidelines.
**The usable volume percentage of a conventional hydropneumatic tank without an air-water separator is assumed to be 20 percent in the absence of any supporting justification stating otherwise.

An alternate method of calculating conventional hydropneumatic tank size is based on Boyle's Law and cut-in and cut-out pressure settings:

$$\text{Gross Volume} = \frac{V_U}{\left(1 - \frac{P_1 + 14.7}{P_2 + 14.7}\right)}$$

V_U = (5 minutes) X (largest booster/transfer pump capacity in gpm) = usable volume in gallons
P_1 = cut-in pressure in psi
P_2 = cut-out pressure in psi

Note: the denominator in the above equation is commonly referred to as the drawdown factor and is the percent usable volume of the tank with the corresponding cut-in and cut-out pressures.

(C) Hydropneumatic tanks when used as the only storage facility (i.e. no atmospheric storage) in conjunction with well pump(s) may be acceptable only for very small public water systems where it is not economically practical or necessary to have an atmospheric storage tank, transfer/booster pump, and hydropneumatic tank system. Hydropneumatic tanks by themselves may provide some equalization storage for very short instantaneous peak demands, however, they should not be used to meet sustained peak demands or for emergency storage. Where hydropneumatic tanks will be used as the only storage facility, the safe yield of the well(s) should be capable of meeting the sustained peak demands of the system, and the tanks should be sized as in section (2)(B) above except the largest well pump capacity should be substituted for the largest booster/transfer pump capacity in the usable volume calculation. Bladder tanks and other non-conventional hydropneumatic tanks should be sized in accordance with manufacturer's recommendations. When sustained peak demands are significantly greater than normal average day demands and it may not be practical nor possible to drill high capacity wells, an atmospheric storage tank in conjunction with a transfer/booster pump and hydropneumatic tank system should be installed and sized in accordance with sections (1)(B) and (2)(B) above.

(D) Hydropneumatic tanks should not be used for fire protection.

(3) Section 19-13-B102(f)(1) of the RCSA requires that all service connections have a minimum water pressure at the water main of 25 psi under normal operating conditions (including normal peak

demands but excluding fire flow demands). When feasible, it is recommended that the minimum water pressure be 35 psi under normal operating conditions. Pressure reducing devices should be provided in areas of the distribution system served by the storage tank where static pressures will exceed 100 psi.

(4) Storage tanks should be sized to achieve a balance between hydraulic requirements and water quality maintenance. Excessive storage capacity should be avoided whenever possible to minimize long detention times and water quality deterioration. If excess capacity is required due to future growth, consideration should be given to a phased approach by designing the storage tank with the capability of being expanded in the future, or space should be provided to construct additional tank(s) to meet additional future demands.

(5) Clearwells may have additional sizing criteria including volume required for plant use (filter backwash, chemical dilution, in-plant domestic needs, etc.), volume required for disinfection contact time, etc., which are not covered in these storage tank guidelines.

General Design and Construction Considerations

(1) Storage tank materials, fabrication, installation/construction, and testing should be in accordance with the most current applicable American Water Works Association (AWWA) standards if available. In the absence of applicable AWWA standards, storage tanks should conform to applicable recognized industry standards and codes, if available, from organizations including, but not limited to, American Society of Mechanical Engineers (ASME), American National Standards Institute (ANSI), American Society for Testing Materials (ASTM), American Concrete Institute (ACI), Underwriters Laboratories (UL), Steel Tank Institute/Steel Plate Fabricators Association (STI/SPFA), etc. to ensure longevity and structural integrity during service. Conventional hydropneumatic tanks should conform to the ASME Boiler and Pressure Vessel Code. Bladder tanks should be certified to NSF/ANSI Standard 61. Plastic tanks should be certified to NSF/ANSI Standard 61.

(2) Special attention should be given to buried or partially buried concrete storage tanks some of which historically have had bacteria problems due to faulty construction, materials, and failing joint seams which allow contamination to infiltrate the tank. Concrete tanks should be designed and constructed in accordance with applicable standards from organizations including, but not limited to, ASTM, National Precast Concrete Association (NPCA), ACI, etc. Concrete tanks should be monolithic (i.e. seamless) and reinforced. If seams are unavoidable they should be sealed watertight and located entirely above grade for visual inspection during tank operation. The minimum 28-day compressive strength of the concrete should be 4,000 psi. Concrete tanks should not be located in areas where there will be vegetation or trees on top of or next to the tank which may cause root damage to the tank.

(3) A detailed geotechnical investigation should be made during the design phase to ensure that the tank foundation will be stable and protected from excessive settlement.

(4) Section 19-13-B102(f)(5)(A) of the RCSA requires that all finished water storage tanks be properly constructed in a sanitary manner and located to prevent storm water and precipitation from entering the tank and contaminating the water. In addition, all tanks should be constructed to protect the stored water from contamination by birds, animals, insects, and excessive dust.

(5) Storage tanks should be watertight and have no openings except for properly installed pipes, appurtenances, and equipment. All penetrations through and connections with the storage tank should be sealed watertight.

(6) Section 19-13-B102(f)(5)(D) of the RCSA prohibits uncovered finished water storage tanks.

(7) Storage tank roofs should be well drained and should not have any low spots or structures that may hold water. Downspout pipes or any other drainage pipes should not enter or pass through the storage tank. For buried concrete tanks consideration should be given to installation of an impermeable membrane roof covering. The ground above and around buried storage tanks should be graded to drain surface runoff at least 25 feet away from the tank roof and prevent ponding on top of the storage tank. The top of ground level and partially buried tanks and reservoirs should be at least two feet above the normal ground surface.

(8) The area surrounding partially buried and ground level storage tanks should be graded to drain surface runoff away from the storage tank. In cases where the storage tank is constructed into or next to a hillside or embankment, means to intercept and drain the surface runoff should be provided.

(9) When the bottom of a storage tank is below normal ground surface, it should be placed above the groundwater table whenever possible. If this is not possible, perimeter foundation/footing drains and exterior tank sealants/impermeable membranes or equivalent should be provided to protect against groundwater infiltration and buoyant forces. Foundation/footing drains should discharge freely to daylight away from the tank whenever possible.

(10) Capability to isolate storage tanks from the distribution system should be provided, and storage tanks should be designed, whenever possible, to minimize service interruptions during periods when the tanks may be out of service for maintenance or emergencies. Duplicate tanks should be constructed whenever feasible.

(11) Inlet/outlet pipes should be adequately protected by the use of flexible joints, preferably ball and socket joints, or equivalent in critical areas of pipe stress such as piping connections to the tank and where differential settlement may occur.

(12) Finished water should not be stored or conveyed in a compartment adjacent to non-potable water when a single wall separates the two compartments.

(13) Storage tanks should be designed to prevent freezing.

(14) Locked fencing should be provided around the perimeter of the storage tank to prevent trespassing, vandalism, and sabotage.

Water Quality Maintenance

(1) Storage tanks should be designed and operated to facilitate adequate turnover and mixing/circulation of stored water to prevent water quality deterioration due to excessive water age (stagnation) and dead spots within the storage tank. Complete turnover is recommended every 3-5 days, however, specific turnover rate should be established based on the stored water quality and/or hydraulic modeling. In general, storage tanks not providing contact time should be designed to promote complete mixing rather than plug flow conditions.

(2) Whenever possible, separate inlets and outlets should be provided. When there is a common inlet/outlet pipe serving the storage tank from the distribution system, the common pipe should be branched into a separate inlet and outlet prior to or inside the storage tank by the use of check valves or equivalent means. The discharge of the inlet and intake to the outlet should be located in such a manner (preferably on opposite sides of the tank and at different elevations [i.e outlet located at tank bottom and inlet located higher near top]) to promote thorough mixing and to prevent hydraulic short-circuiting and stagnant zones especially for storage tanks with a large length/height to diameter/width ratio. In general, tangential inlets parallel to the tank sidewall and deflectors that direct flow towards tank walls should be avoided. In cases where it may not be possible to have separate inlets/outlets, a mixing and circulation system should be installed or the inlet momentum (flow x velocity) and inlet diameter and configuration should be evaluated and sized to ensure thorough mixing during fill cycles and to prevent “last-in, first-out” conditions.

(3) Special attention should be given to storage tanks, especially standpipes, that may be prone to thermal stratification.

Materials

(1) The storage tank materials and products should not cause the water delivered to the customers to become impure, unhealthy, and non-potable, produce aesthetic problems such as taste and odors, or promote bacterial growth after being placed into active service. All storage tank and appurtenant materials and products including, but not limited to, paints, linings, coatings, adhesives, lubricants, bladders, gaskets, and sealants in direct contact with potable water should be certified to NSF/ANSI Standard 61. All storage tank materials and products in contact with stored water should be compatible with the stored water quality.

(2) The storage tank materials should be capable of withstanding all internal and external forces to which they may be subjected while in service.

(3) Metallic materials should be protected against internal and external corrosion.

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Coating and Cathodic Protection

(1) Coatings and cathodic protection systems should conform to the most current applicable AWWA standards if available. In the absence of applicable AWWA standards, coatings and cathodic protection systems should conform to applicable recognized industry standards and codes, if available, from organizations including, but not limited to, National Association of Corrosion Engineers (NACE), SSPC (Society of Protective Coatings), NSF, STI/SPFA, etc.

(2) Interior and exterior coatings should be able to withstand conditions to which they may be subjected to while in service.

(3) Interior coatings should be properly applied and cured in accordance with applicable standards or manufacturer's recommendations to prevent leaching of substances into the stored water. Whenever possible 100 percent solids coating systems should be used.

(4) When feasible, interior coatings should be used in conjunction with a cathodic protection system for maximum corrosion protection.

(5) Cathodic protection access plates should be sealed watertight.

Appurtenances

(1) Section 19-13-B102(f)(5)(A) requires that all atmospheric storage tanks be equipped with a suitably protected and screened overflow. In addition, Section 19-13-B102(f)(5)(A) of the RCSA requires that overflows not be directly connected to any sanitary sewer or storm drainage system. Overflows should be of sufficient diameter to permit overflow of water in excess of the maximum storage tank fill rate. Overflow pipes should discharge over a drain inlet, basin, splash plate, sump (for indoor installations), or equivalent to prevent erosion around the tank foundation/support or pooling. Overflows on tall ground level storage tanks, elevated storage tanks, and standpipes should terminate 12-24 inches above the ground surface. Overflows on buried and partially buried tanks should discharge to daylight and be provided with an air gap (two pipe diameters) above the flood rim of the drain inlet, basin, splash plate, or equivalent drainage structure. Vents should not be used as overflows.

(2) Section 19-13-B102(f)(5)(A) requires that all atmospheric storage tanks be equipped with a suitably protected and screened vent. Vents should be designed to prevent differential pressures between the inside and outside of the storage tank which may cause structural damage to the storage tank. Vents on above grade tanks should terminate at least three pipe diameters above the tank roof. Vents on buried, partially buried, and short ground level storage tanks should terminate in an inverted "J" manner 24-36 inches above grade or tank roof. Overflows should not be used as vents. Vents should be located above the overflow level of the tank such that during an overflow condition there would be no water overflowing through the vent. Whenever possible automatically resetting "fail-safe" vents should be used to protect the tank in the event a vacuum occurs due to a clogged vent screen.

(3) Vents and overflows should be equipped with a minimum 24-mesh noncorrodible screen. Roof vents on standpipes and elevated storage tanks may be equipped with a 4-mesh screen. Overflows may be equipped with a flap valve or elastomeric check valve (duckbill valve), however, a 24-mesh screen located inside the overflow is still recommended in conjunction with the flap or duckbill valve. Flap valves and elastomeric check valves should be designed and operate such that they will close completely, seal tightly, and not stick open.

(4) Vents and overflows should be designed to prevent rain water, animal droppings, ceiling particulates (for indoor installations), dirt, debris, etc. from falling into the storage tank.

(5) Atmospheric storage tanks should be provided with a means to monitor water level.

(6) When feasible, atmospheric tanks should be equipped with a filler pipe to allow for water to be trucked in case of emergencies. The filler pipe should be capped and locked.

(7) Atmospheric storage tanks should be equipped with access hatches and/or manholes for cleaning, painting, inspection, and maintenance. Roof hatches should be provided with a frame that extends at least four inches above the roof and fitted with a solid watertight, gasketed cover which overlaps and extends down around the frame at least two inches. Manholes should be sealed watertight with a gasket and for buried and partially buried tanks should be elevated a minimum of 24 inches above the top or covering sod. Concrete manhole risers should be watertight and monolithic whenever possible. All access hatches and manholes should be locked.

(8) Hydropneumatic tanks should be equipped with a pressure gauge, air blow-off, means for adding air, pressure-operated start/stop controls for the pumps, and pressure relief valve. Conventional hydropneumatic tanks without an air-water separator should be further equipped with a sight glass to monitor air/water ratio and a watertight access manhole. When on-site permanent air compressors are utilized to maintain the required air pressure within the tank, they should be of the oil-less type with a screened air intake.

(9) Storage tanks should be provided with a means for drainage. Draining the tank into the distribution system should not be an acceptable method. Drains should drain to daylight and should be provided with a 24-mesh noncorrodible screen, flap valve, elastomeric check valve, or removable cap/plug. Provisions should be made to prevent erosion around the tank foundation or support. Drains should not be directly connected to any sanitary sewer, storm drain, or sump. The tank bottom should be sloped towards the drain.

(10) Discharge pipes should be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided on vertical outlets. Means to remove accumulated sediment should be provided.

(11) Sample taps or hydrants should be installed to allow for collection of water quality samples representative of water stored in the storage tank. Storage tanks that have separate inlet and outlet pipes should have separate sample taps on the inlet and outlet pipes.

(12) Controls should be provided to maintain levels in storage tanks. Float switches that contain mercury should not be used.

(13) Alarms should be provided indicating, at a minimum, high and low water levels.

(14) Consideration should be given to appurtenances, especially vents and overflows, that may be subject to freezing and improper functioning.

(15) Chambers, pits, or manholes containing storage tank valves and appurtenances should be located, to the extent feasible, to prevent flooding or adequately drained to keep the pit dry. Where gravity drainage is not practical and a sump pump or other mechanical means are employed to drain the water to a storm sewer or other drainage system, a check valve should be installed on the pump discharge line and the discharge located above the normal flow elevation in the receiving chamber or pipe. In no instance should a drain be connected directly to any sanitary sewer.

Yard Piping

(1) The applicable sections of the Water Main Guidelines should be used for storage tank yard piping including, but not limited to, Materials, Appurtenances, Installation, and Testing and Disinfection.

Disinfection and Water Quality Testing

(1) Section 19-13-B47 of the RCSA requires that all storage tanks be disinfected after construction is completed. Disinfection should be in accordance with the most current version of AWWA Standard C652. Chemicals used in the disinfection process should be certified to NSF/ANSI Standard 60.

(2) After disinfection but prior to placing the storage tank into active service, a water sample representative of stored water in the storage tank should be collected and analyzed, at a minimum, for total coliform bacteria, total and free chlorine residual, physical parameters, and VOCs. Test results, with the exception of chlorine, should meet the water quality standards shown in Table 1 on the following page prior to placing the storage tank into active service. Samples should be collected after chlorine levels have been reduced to levels typically found in the system.

Table 1 – Water Quality Standards

Parameter	Standard
Total Coliform Bacteria	0 or absent (should use membrane filter (MF) technique unless HPC testing is conducted in which case the presence-absence technique may be substituted for the MF technique)
Color	< 15 CU
Turbidity	< 5 NTU
Odor	< 2
pH	range 6.4 – 10
VOCs	refer to RCSA Section 19-13-B102(e)(4)

(3) A repeat sample should be collected and be in compliance if the original sample is not in compliance with the standards noted in Table 1. If the original total coliform bacteria sample is positive, two repeat enumerated total coliform samples should be collected at least 24 hours apart. If two consecutive samples show the presence of total coliform bacteria, the storage tank should be disinfected again in accordance with Section (1) above.

(4) Chlorine levels should be reduced to levels found normally in the distribution system before the water is used for consumption.