STATE OF CONNECTICUT DEPARTMENT OF PUBLIC HEALTH
DRINKING WATER SECTION

TECHNICAL GUIDELINES FOR DETERMINING DISINFECTION "CT" WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SOURCES OF SUPPLY

Effective Date: April 8, 2010

Authority: Section 19-13-B102(d)(2) of the Regulations of Connecticut State Agencies (RCSA) requires approval from the Department of Public Health (DPH) of treatment works prior to construction. In addition, Section 19-13-B80 of the RCSA requires the review and approval by the DPH of plans and specifications for any chemical treatment system. 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.

As required in Section 19-13-B102(e)(7)(M) of the RCSA, when a groundwater source not under the direct influence of surface water is chlorinated, a free chlorine residual of at least 0.2 mg/l after ten (10) minutes contact, or the equivalent thereof, shall be used.

These guidelines also include the necessary information for a Public Water System (PWS) to determine compliance with the treatment technique requirements of the Ground Water Rule (GWR), which became effective December 1, 2009. A PWS is required to conduct triggered source water monitoring as a result of a routine bacteriological compliance sample that is total coliform-positive if the system does not have a DPH approved disinfection system that reliably provides at least 4-log inactivation of viruses before or at the first customer. A PWS with an installed disinfection system not approved by the DPH to achieve 4-log inactivation of viruses may be required to conduct source water assessment monitoring.

A PWS seeking DPH approval for disinfection treatment that will provide 4-log inactivation of viruses must submit documentation to the DPH for review demonstrating that its disinfection system can reliably achieve and maintain at least 4-log inactivation of viruses before or at the first customer, and that a compliance water sample location (sample tap or analyzer) is adequate for compliance monitoring. The documentation must include engineering, operational or other relevant information for the DPH to evaluate the submission. A written approval must be obtained from the DPH for a PWS's disinfection treatment which will establish a minimum residual chlorine concentration that will be required to be maintained at a compliance sampling location and terms under which a water treatment plant must be operated. For more information, please refer to the DPH's website at http://www.ct.gov/dph/publicdrinkingwater and EPA's Groundwater Rule website at http://www.epa.gov/safewater/disinfection/gwr/index.html.

Definitions

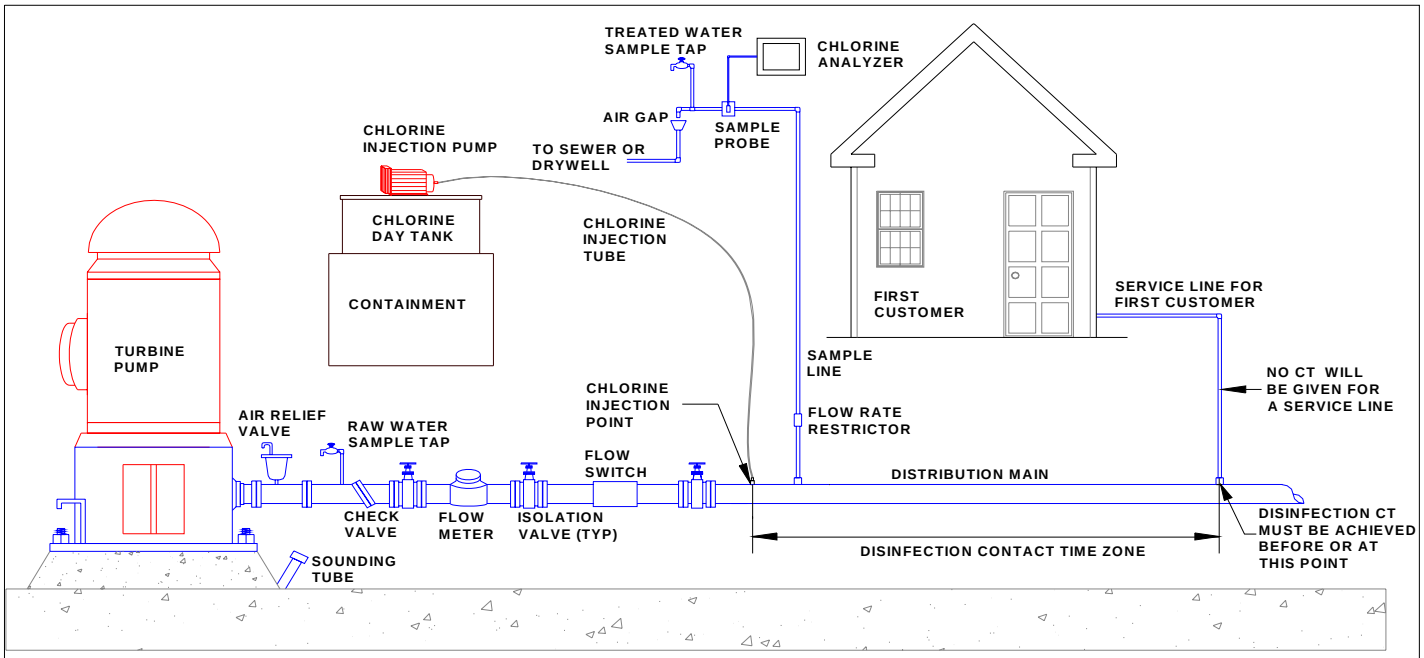
(1) Chlorination: in these guidelines means the use of chlorine, sodium hypochlorite, or calcium hypochlorite for disinfection. Chlorine dioxide, chloramines and other types of disinfectants are not covered in these guidelines. These guidelines are primarily intended to only cover disinfection of groundwater sources of supply and not surface water or groundwater under the direct influence of surface water although some sections may be applicable to disinfection of all sources of supply.

TECHNICAL GUIDELINES FOR DETERMINING DISINFECTION "CT" WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SOURCES OF SUPPLY

If a PWS well is determined to have the presence of Cryptosporidium and Giardia, disinfection with chlorine alone would not be acceptable to the DPH.

(2) CT: per Section 19-13-B102(a)(22) of the RCSA "means the product of the residual disinfectant concentration (C) in milligrams per liter (mg/l) determined before or at the first customer, and the corresponding disinfectant contact time (T) in minutes (i.e., "C" X "T")." CT is typically expressed as mg-min/L (milligrams - minute per liter).

The first customer is the location (i.e., residential, commercial, industrial building, treatment facility, etc.,) where water is first consumed or provided. No CT will be given for a service line since a service line is not under the control of a PWS and the flow rate in the service line is not uniform. CT needs to be achieved from the point of chlorine injection to a location before or at the first service tap, connection, or tee on a system with distribution mains. On a small system without a distribution system, CT is to be achieved from the point of chlorine injection up to a location in the plumbing system before or at the first tee or split. Please see illustration below:



TYPICAL CHLORINATION SYSTEM INSTALLATION

TECHNICAL GUIDELINES FOR DETERMINING DISINFECTION "CT" WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SOURCES OF SUPPLY

Dosage and Residual

(1) For surface water and groundwater under the direct influence of surface water, Section 19-13-B102(e)(7)(M) of the RCSA requires that water entering the distribution system be exposed to disinfection in accordance with Section 19-13-B102(j)(3)(B) of the RCSA. The requirements of these regulations are not covered in these guidelines.

(2) For chlorinated groundwater not under the direct influence of surface water, Section 19-13-B102(e)(7)(M) of the RCSA requires a minimum free chlorine residual of at least 0.2 mg/L after 10 minutes of contact time or equivalent. The product of free chlorine residual and contact time is known as CT. Therefore, the minimum required CT is 2 mg-min/L (i.e. 0.2 mg/L X 10 minutes). This CT value must be achieved before or at the first customer as noted in the definition for CT. Note that a higher free chlorine residual and lower contact time may be used to meet the required CT. For example, a free chlorine residual of 0.4 mg/L in conjunction with a contact time of 5 minutes will still satisfy the CT requirement of 2 mg-min/L (i.e. 0.4 mg/L X 5 minutes = 2 mg-min/L).

(3) For a PWS that chooses to operate its disinfection treatment to maintain at least 4-log inactivation of viruses pursuant to the GWR or is mandated by the DPH to provide at least 4-log inactivation, a CT of at least 6 mg-min/L which corresponds to a minimum residual chlorine concentration of no less than 0.2 mg/L after 30 minutes of contact time or equivalent must be achieved before or at the first customer. A CT of 6 mg-min/L is based on well water with a pH value of 6.0-9.0 and a water temperature of 10 degrees Celsius. If it is demonstrated that the pH value and/or temperature differs from these levels, a different CT value will be required.

(4) A chlorine demand test should be performed in accordance with *Standard Methods for the Examination of Water and Wastewater* to determine the initial chlorine dosage. It is important to note that inorganic compounds found in groundwater such as iron, manganese, and sulfides will initially reduce the chlorine residual (i.e. create a chlorine demand), and these must be accounted for when determining the initial dosage. In lieu of performing a chlorine demand test, small PWS can use the following more general method as a rough estimate for the initial chlorine dosage:

$$\text{chlorine dosage (mg/l)} = (\text{chlorine residual in mg/l}) + (\text{mg/l of Fe}) + (\text{mg/l of Mn}) + (\text{mg/l of } H_2S \text{ x } 4)$$

(5) Section 19-13-B102(e)(7)(M) of the RCSA requires that daily free chlorine residual readings be taken once chlorination system is in active service. Free chlorine residual readings shall be taken from a location that is representative of the minimum required contact time necessary to achieve CT before or at the first customer.

Sample lines may be used to demonstrate equivalency of contact time, however, the contact time in the sample line must be at least equivalent to the required contact time before or at the first customer. In cases where the contact time in a sample line is greater than the contact time required before or at the first customer, the same free chlorine residual that is required to achieve CT before or at the first

customer must still be maintained at the sample location. The following two examples illustrate the requirements of this subsection:

Example 1) It is determined that the contact time from the chlorination point to the first customer is 10 minutes, and therefore, a minimum free chlorine residual of 0.2 mg/L is required to be maintained at the first customer location. A sample line is installed with an equivalent contact time of 10 minutes. Therefore, the minimum free chlorine residual reading at the sampling location must be 0.2 mg/L.

Example 2) It is determined that the contact time from the chlorination point to the first customer is 5 minutes, and therefore, a minimum free chlorine residual of 0.4 mg/L is required to be maintained at the first customer location. A sample line is installed with a contact time of 10 minutes, and the PWS proposes to maintain a minimum free chlorine residual at the sampling location of 0.2 mg/L. In this case, the minimum free chlorine residual of 0.2 mg/L would not be accepted, and a minimum free chlorine residual of 0.4 mg/L would need to be maintained at the sampling location.

(6) The GWR requires a PWS serving a population of greater than 3,300 people, and which has obtained approval from the DPH for its chlorination system which will provide 4-log inactivation of viruses to continuously monitor the residual disinfectant concentration. A PWS serving a population of less than 3,300 people can and may choose to use a continuous chlorine analyzer to monitor the residual disinfectant level in the treated water. If no continuous chlorine analyzer is installed, a system serving 3,300 or fewer people must take a daily grab sample during the hour of peak flow or at another time concurred upon by the DPH. The residual chlorine concentration must be measured using an analytical method specified in 40 CFR 141.74(a)(2), as amended from time to time, at a location approved by the DPH. A PWS using a continuous chlorine analyzer must record the lowest daily residual disinfection concentration measurement and maintain for reference. The daily readings of residual chlorine must be reported to the DPH monthly using a form available on the DWS website.

If there is a failure in the continuous monitoring equipment, PWS must conduct a grab sampling every four hours until the continuous monitoring equipment is returned back to service. The PWS must resume its continuous residual disinfectant monitoring within 14 days.

Note:

The system's hour of peak flow is the largest hourly volume of water consumed. The hourly peak flow can be determined by recording the meter readings of the well(s) on an hourly basis.

(7) Whenever possible, continuous chlorine analyzers and recorders with integrated alarms to indicate low and high free chlorine residual levels should be installed. Additionally, a means to alert a PWS representative or certified operator (i.e. dialer or SCADA) of the alarm should be provided.

TECHNICAL GUIDELINES FOR DETERMINING DISINFECTION "CT" WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SOURCES OF SUPPLY

Contact Time

(1) Adequate contact time is critical to ensure that the applied chlorine has adequate time to provide effective kill/inactivation of pathogenic organisms that may be present in the water. Contact time is typically achieved in a storage or contact tank following the chlorine application and may also be achieved in pipelines depending on the location of the first customer. Theoretical contact time is calculated as follows:

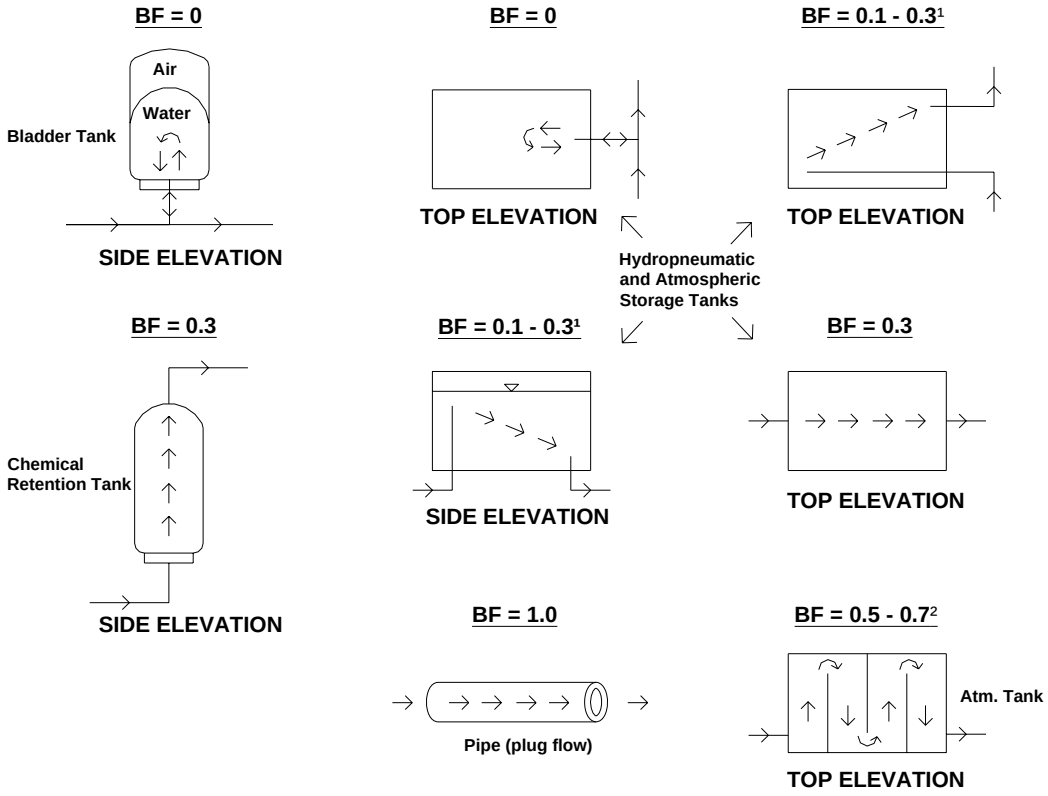
$$T = \frac{V}{Q}$$

T = contact time in minutes
V = volume of storage facility or pipe in gallons
Q = maximum flow rate in gpm

a) For a PWS with well(s) and only operates with a pressure tank(s), the maximum flow rate to be used is the maximum capacity of the well(s).
b) For a PWS that uses atmospheric tank(s) in conjunction of booster pump(s), the maximum flow rate to be used is the maximum flow of the booster pump(s).
c) For the sample line used to convey water to a compliance sample tap or analyzer, the maximum flow rate to be used is the maximum flow through the sample line. The flow in the sample line must be constant.
d) To ensure that the minimum required equivalent contact time is maintained in the sample line, a flow restrictor may be necessary for installation on the sample line.

(2) Since poor circulation (i.e. short circuiting) in a storage or contact tank will reduce the contact time, T as calculated above is typically multiplied by a conversion or baffling factor to account for poor circulation. The diagrams on the following page show typical types of storage tanks, inlet/outlet pipe configurations, and corresponding recommended baffling factors (BF):

TECHNICAL GUIDELINES FOR DETERMINING DISINFECTION "CT" WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SOURCES OF SUPPLY



Note that bladder tanks and atmospheric or hydropneumatic tanks with a single inlet and outlet are not given contact time credit since during a pump-on cycle, some of the water is bypassing the tank.

Footnotes:
[1] The recommended BF for tank configurations with separate inlets and outlets is 0.1 if the inlet pipe is not extended in the tank and up to 0.3 if the inlet pipe is extended as far in the tank as possible.
[2] See table on following page.

(3) For configurations not shown above, the following table can be utilized for recommended baffling factors:

Baffling Condition	Baffling Description	Baffling Factor
Unbaffled	Mixed flow, very low length-to-width ratio, high inlet and outlet flow velocities	0.1
Poor	Single or multiple unbaffled inlets and outlets, no intrabasin baffles	0.3
Average	Baffled inlet or outlet with some intrabasin baffles	0.5
Superior	Perforated inlet baffle, serpentine or perforated intrabasin baffles	0.7
Perfect	Plug flow; very high length-to-width ratio (pipeline flow), perforated inlet, outlet, and intrabasin baffles	1.0

Note: Table taken from EPA *LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual*

(4) If a baffling factor is proposed that is higher than the recommended values, a tracer study should be conducted to confirm the proposed baffling factor. In the absence of a tracer study, supporting justification from the tank manufacturer or equivalent should be provided.

Calculating CT:

The following procedure explains how to determine if adequate CT is provided:

(1) Determine the total contact time available from the point of chlorine injection to the first customer during the maximum expected flow rate.

(a) for pipes, contact time is calculated as follows:

$$T = \frac{\left(0.785d^2\right)\times\left(L\right)\times\left(7.48\right)}{Q}$$

T = contact time in minutes
d = pipe diameter in feet
L = length of pipe in feet
Q = maximum expected flow rate in gpm

Note that for pipes, the baffling factor is 1.0. In cases where the well discharge piping tees into a water main causing the flow to split prior to the first customer, it must be assumed, in the absence of any supporting information, that all of the flow from the well is in one direction at the tee towards the first customer. A hydraulic model or equivalent supporting information may be used to justify a more accurate flow rate split.

(b) for storage tanks, contact time is calculated as follows:

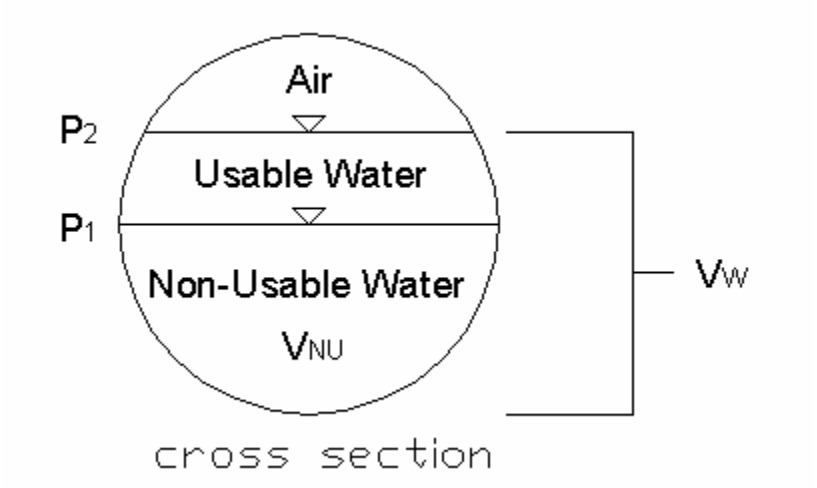
$$T = \left(\frac{V}{Q}\right) \times BF$$

T = contact time in minutes
Q = maximum expected flow rate through the tank in gpm
BF = baffling factor from Contact Time section above. Note that bladder tanks and atmospheric/hydropneumatic tanks with a common inlet/outlet cannot be used for chlorine contact time.
V = volume of tank at lowest normal operating water level in gallons. Note: this is not the gross volume of the tank unless the tank is a "flow through" type pressure contact vessel where the entire gross volume of the tank is water.

For hydropneumatic tanks with separate inlets and outlets, V can be calculated by the following procedure which is based on Boyle's Law:

$$V_{NU} = 100 - \left[\left(\frac{P_2 + 14.7}{P_1 + 14.7} - 1\right)(100 - V_W) + (100 - V_W)\right]$$

V_{NU} = non-usable water as percentage of total tank volume
P_1 = cut-in pressure in psi
P_2 = cut-out pressure in psi
V_W = percentage of total water in tank at P_2 in relation to total tank capacity (may be estimated using a sight tube for existing tank installations)



V in gallons can then be calculated as follows:

$$V = \left(\frac{V_{NU}}{100}\right) \text{ x Gross Volume of Tank}$$

If the above procedure is not utilized to calculate V in a hydropneumatic tank, supporting information/calculations will be required to justify an alternative V calculation.

(c) add up the total contact time available in minutes.

(2) Calculate CT provided as follows:

$$CT = (C) \times (T)$$

CT = mg-min/L
C = target free chlorine residual in mg/L
T = total contact time provided in minutes (from step 1 above)

(3) If the CT provided value in step (2) above is greater than or equal to 2 mg-min/L, then the CT provided is adequate pursuant to Section 19-13-B102(e)(7)(M) of the RCSA.

(4) In lieu of step (3), the minimum free chlorine residual required can be calculated as follows:

$$C = \frac{2 \text{ mg - min/L}}{T}$$

C = minimum free chlorine residual required in mg/L
T = total contact time as calculated in step (1)

(5) If the CT provided value in step (2) above is greater than or equal to 6 mg-min/L, then the CT value is adequate to achieve 4-log inactivation of viruses under the GWR. The DPH will only consider approval of 4-log inactivation of viruses for systems that would maintain a CT of at least 6 mg-min/L, which corresponds to a minimum residual chlorine concentration of no less than 0.2 mg/L after 30 minutes of contact time or equivalent at a location before or at the first customer.

(6) If CT provided as calculated in step (2) is less than 2 mg-min/L pursuant to Section 19-13-B102(e)(7)(M) of the RCSA or 6 mg-min/L under the GWR, the following options may be considered:

(a) increase the target free chlorine residual as practically feasible and taking into account DBP formation potential as well as taste and odor concerns.
(b) increase the contact time by modifying existing piping configuration or adding more storage tank(s). In some cases adding a pipe loop or relocating a service line may

provide the additional contact time needed. Note that any piping prior to the first customer may be used in CT calculations.

(7) The CT will need to be substantially increased to higher than 6 mg-min/L if the pH of the water to be treated is greater than 9.0 to provide effective disinfection pursuant to the GWR.

(8) Minimum free chlorine residual values calculated should be rounded up to the nearest 0.05 mgL increment.

(9) For systems that disinfect using liquid chlorine and are claiming 4-log inactivation of viruses based on pipe contact time only, an EPA GWR disinfection contact time calculator is available at: http://www.epa..gov/OGWDW/disinfection/gwr/compliancehelp.html. The calculator is designed to help PWSs determine minimum virus log inactivation at each treatment facility. This spreadsheet will automatically calculate the log inactivation achieved by a facility. The spreadsheet has been designed to calculate the log inactivation provided by a PWS's treatment train based on various operating parameters (i.e. flow rate, pH, temperature, disinfectant concentration, peak flow rate, etc.).