R309-520. Facility Design and Operation: Disinfection

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R309-520. Facility Design and Operation: Disinfection.

R309-520-1. Purpose.

This rule specifies requirements for facilities that disinfect public drinking water. It is to be applied in conjunction with Rule Series 500, Drinking Water Facility Construction, Design, and Operation, namely, R309-500 through R309-550. Collectively, these Rules govern the design, construction, and operation and maintenance of public drinking water system facilities. These Rules are intended to assure that such facilities are reliably capable of supplying adequate quantities of water that consistently meet applicable drinking water quality requirements and do no harm to general public health.

R309-520-2. Authority.

This rule is promulgated by the Drinking Water Board as authorized by Title 19, Environmental Quality Code, Chapter 4, Safe Drinking Water Act, Subsection 104(1)(a)(ii) of the Utah Code and in accordance with Title 63G, Chapter 3 of the same, known as the Administrative Rulemaking Act.

R309-520-3. Definitions.

Definitions for certain terms used in this rule are given in R309-110 but may be further clarified herein.

R309-520-4. Primary Disinfectants.

Primary disinfection is the means to provide adequate levels of inactivation of pathogenic micro organisms within the treatment process. The effectiveness of chemical disinfectants is measured as a function of the concentration and time of contact, a "CT" value in units such as mg/L-min. The effectiveness of UV disinfection is determined through validation testing of each model and specific configuration of UV reactor proposed in the design, as described in R309-520-8.

Only four disinfectants: chlorine (i.e., gas, hypochlorite solution, and hypochlorite tablets), ozone, ultraviolet light, and chlorine dioxide are approved herein as allowable primary disinfectants of drinking water.

Guidance: Iodine disinfection is no longer allowed because of adverse health implications for the public.

R309-520-5. Secondary Disinfectants.

Secondary disinfection is the means to provide an adequate disinfectant residual in the distribution system to maintain a chemical barrier and to control bacteriological quality of treated water.

The effectiveness of secondary chemical disinfection is measured through maintaining a detectable disinfectant residual throughout the distribution system. Allowable secondary disinfectants are chlorine (gas, hypochlorite solution, and hypochlorite tablets) and chloramine.

R309-520-6. General.

(1) Continuous Disinfection

Continuous disinfection is required of all ground water sources that do not otherwise continuously meet standards of bacteriologic quality. Intermittent or batch disinfection, commonly used for disinfecting new water tanks, waterlines, well casings, etc., is not acceptable for ongoing drinking water delivery service. Surface water sources, and ground water sources under direct influence (UDI) of surface water, shall be disinfected as a part of the treatment requirements for conventional surface water treatment or alternative surface water treatment.

Disinfection is not an acceptable remedy to inadequate drinking water system facilities. Systems that practice source disinfection, and whose sources are exclusively ground water sources, as defined in R309-505-8, shall meet the requirements of R309-105-10(1), Chemical Addition.

Guidance: Temporary disinfection of a water source newly discovered as failing bacteriological water sampling result standards may be prudent public health policy. However, permanent disinfection is not regarded as a satisfactory resolution of the situation. That is, disinfection cannot be used to simply mask ongoing bacteriological contamination of a water source. The root cause of the failed bacteriological water quality at the source must be rectified.

(2) ANSI/NSF Standard 60 Certification

All chemicals, including chlorine (i.e., gas, hypochlorite solution, hypochlorite tablets, granules, and powder), chloramines, and chemicals used to generate chlorine dioxide, added to drinking water supplied by a public water system shall be certified as complying with ANSI/NSF Standard 60, Drinking Water Treatment Chemicals.

Guidance: Hypochlorite tablets for swimming pools are not approved for drinking water. The swimming pool grade hypochlorite tablets contain additional chemicals, intended to retard the photodecomposition of hypochlorite in swimming pools, and typically lack approval for use in drinking water. Sodium chloride (NaCl) used for on-site hypochlorite generation, as well as water softener resin regeneration, shall be certified as complying with ANSI/NSF Standard 60, Drinking Water Treatment Chemicals. Ammonia gas (often termed agricultural ammonia) used in the ammonification process for on-site choramine disinfectant generation shall be certified as complying with ANSI/NSF Standard 60, Drinking Water Treatment Chemicals.

(3) Appropriate Use of Primary and Secondary Disinfectants

Surface water, or groundwater under the direct influence of surface water, shall be filtered and disinfected.

Only ground water not under the influence of surface water can be adequately disinfected with primary disinfectants, or primary and secondary disinfectants, alone. Surface waters, as well as ground water under the direct influence of surface water, require conventional surface water treatment or alternative surface water treatment methods.

(4) Required Disinfectant Dose and Contact Time

Minimum cyst and virus reductions for that approved primary chemical disinfectants must achieve are specified in R309-200-5(7)(a), Disinfection, and reiterated in R309-200-7(2), namely 4-log virus removal or inactivation, 3-log Giardia lamblia cyst removal or inactivation, and 2-log Cryptosporidium removal or inactivation for water sources in bin 1 classification per R309-215-15(11)(c). Minimum doses and contact times for primary chemical disinfectants are standardized as "CT" values as defined in R309-110-4, Definitions.

(5) Site Selection

Disinfection installations shall be sited to permit convenient year-round access. These installations shall initially be sited with due consideration of possible danger to nearby population and of possible jeopardy from seismic fault zones.

Guidance: Public water systems shall work closely with local fire suppression authorities to evaluate public hazards associated with on-site use of chorine gas, especially, when subdivisions or other populations newly encroach upon previously remote facilities or when new geologic hazards are identified.

R309-520-7. Chlorine.

(1) General Requirements for all Chlorination Installations.

(a) Chemical Types.

Disinfection by chlorination shall be accomplished by gaseous chlorine or liquid solutions of calcium hypochlorite or sodium hypochlorite.

(b) Feed Equipment.

Solution-feed gas type chlorinators, direct-feed gas type chlorinators or hypochlorite liquid feeders of a positive displacement type shall be provided. Solution-feed gas type chlorinators are preferred. However, for small supplies requiring less than four pounds per day, liquid hypochlorite feed systems are advised.

(c) Chlorine Feed Capacity.

The design of each chlorinator shall permit:

(i) the chlorinator capacity to be such that a free chlorine residual of at least 2 mg/l can be maintained in the system after 30 minutes of contact time during peak demand. The equipment shall be of such design that it will operate accurately over a feeding range of 0.2 mg/l to 2 mg/l.

(ii) assurance that a detectable residual, either combined or free, can be maintained at all times, at all points within the intended area in the distribution system.

(d) Automatic Proportioning.

Automatic proportioning chlorinators shall be required where the rate of flow of the water to be treated or chlorine demand of the water to be treated is not reasonably constant.

Guidance: Chlorine gas chlorinators that respond to a 4-20 milliamp signal from an electronic flow meter are recommended for flow-proportioning. Chlorine gas chlorinators that respond to on-line chlorine residual concentration feedback signal are recommended for dose-proportioning.

(e) Injector/diffuser.

(i) Location. The chlorine solution injector/diffuser shall be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point.

(ii) Equipment. Each injector selected shall be appropriate to the intended point of application with particular attention given to the quantity of chlorine to be added, the maximum injector water flow, the back pressure of the to-be-treated water flow, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure at the inlet and outlet of each injector shall be provided.
(iii) Protection. A suitable screen to prevent small debris from clogging a chlorine injector shall be provided on each water feed line. Provision for flushing of the screen is required.

(f) Contact Time and Point of Application.

(i) Due consideration shall be given to the contact time of the chlorine in water with relation to pH, ammonia, taste producing substances, temperature, biological quality, and other pertinent factors.

(ii) Where possible, the design shall minimize the formation of chloro-organic compounds. At plants treating surface water or ground water under the direct influence of surface water, provisions shall be made for applying chlorine to raw water, applied water, filtered water, and water entering the distribution system.

(iii) When treating ground water, provisions shall be made for applying chlorine to at least a reservoir inlet or transmission pipeline which will provide sufficient contact time.

(iv) Care must be taken to assure that the point of application will, in conjunction with the pipe and tank configuration of the water system, allow required CT values to be achieved prior to the first consumer connection.

(g) Minimization of Chlorinated Overflow.

The chlorinator and associated water delivery facilities shall be designed so as to minimize the release of chlorinated water into the environment, for example, discharge chlorinated water from tank overflows. Such release must comply with rules of Division of Water Quality that pertains to discharge or pollution.

(h) Feed Water Piping.

The chlorinator water supply piping shall be designed to prevent contamination of the treated water supply by make-up water of lesser quality. At all facilities treating surface water, pre-chlorination and post-chlorination systems shall be independent where pre-chlorination chlorine solution make-up water is not finished water. All chlorine solution make-up water shall be at least of equal quality to the water receiving the chlorine solution.

(i) Flow Measurement.

The chlorination system design shall have a means to measure the flow rate of treated water, which is critical to operation of flow-proportioned disinfectant dosing.

Guidance: In most circumstances, a commercial flow meter will be necessary to satisfy this requirement. In unusual circumstances, for example, where the availability of electrical power may be problematic, an exception-to-rule may be warranted to allow the use of a calibrated staff gauge or a calibrated v-notch weir, in an appropriate hydraulic structure such as a surface water intake box or a spring collection box outlet wall.

(j) Residual Testing Equipment.

Chlorine residual test equipment, in accordance with the analytical methods in "Standard Methods for the Examination of Water and Wastewater," shall be provided and shall be capable of measuring residuals to the nearest 0.1 mg/l in the range below 0.5 mg/l, to the nearest 0.3 mg/l between 0.5 mg/l and 1.0 mg/l and to the nearest 0.5 mg/l above 1.0 mg/l.

Guidance: Automatic chlorine residual recorders shall be provided where the chlorine demand varies appreciably over a short period of time. The N,N-Diethyl-p-phenylendiamine (DPD) method of chlorine residual determination is recommended.

(k) Standby and Backup Equipment.

A spare parts kit shall be provided and maintained for all chlorinators to repair parts subject to wear and breakage. If there could be a large difference in feed rates between routine and emergency dosages, multiple gas metering tubes shall be provided, at least one for each dose range, to assure accurate control of the chlorine feed under both routine and emergency conditions. Where chlorination is required for disinfection of a water supply, standby equipment of sufficient capacity shall be available to replace the largest unit in the event of its failure. Standby power shall be available, during power outages, for operation of chlorinators where disinfection of the water supply is required.

(l) Heating, Lighting, Ventilation.

Chlorinator houses shall be heated, lighted and ventilated as necessary to assure proper operation of the equipment and to facilitate its serviceability.

(m) Bypass-to-Waste Capability of Chlorine Disinfection Systems.

A chlorinator bypass, with appropriate turn-out of un-chlorinated water, shall be provided to allow the flow to waste for periods when the chlorination system is not operational. This is necessary to prevent un-chlorinated water from entering the distribution system. The flow to waste shall be designed such that it does not result in unintended consequences such as flooding or property damage.

(n) Isolation Capability.

Chlorinator isolation plumbing shall be provided such that each chlorinator can be removed from the process train (e.g., during maintenance, power outage, other shutdown, etc.) without allowing otherwise unchlorinated water to bypass the unit and be delivered to the public for consumption.

(2) Additional Requirement for Gas Chlorinators.

(a) Automatic Switch over.

Automatic Switch over of chlorine cylinders shall be provided, where necessary, to assure continuous disinfection.

(b) Injector and Eductor.

Each injector or eductor shall be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum injector or eductor water flow, the total discharge back pressure, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure at the inlet and outlet of each injector shall be provided.

(c) Gas Scrubbers.

Gas chlorine facilities shall conform with the Uniform Fire Code, Article 80 and the Uniform Building Code, Chapter 9 as they are applied by local jurisdictions in the state. Furthermore, local toxic gas ordinances shall be complied with if they exist.

(d) Heat.

The design of the chlorination room shall assure that the temperature in the room will never fall below 32 degrees F or that temperature required for proper operation of the chlorinator, whichever is greater.

Guidance: Chlorinator rooms shall be heated to 50 degrees F, and be protected from room temperatures in excess of 70-80 degrees F. Where space heaters are used, the cylinders shall be protected from direct heat. Care must be taken to avoid chlorine condensation in feed lines caused by the feed equipment being cooler than the chlorine cylinder.

(e) Ventilation.

Chlorination equipment rooms which contain chlorine cylinders, tanks, equipment and gaseous chlorine lines under pressure shall have at least one exhaust fan and shall be constructed and equipped such that:

Guidance: For the safety of the operators, chlorination facility shall not be located in a vault that has inadequate ventilation or in a location that is considered a confined space.

(i) chlorine room exhaust fan(s), when operating, shall provide at least one complete room air change per minute;

(ii) chlorine room ventilating fan(s) shall take suction inside the chlorine room near the floor, as far as practical from the door and air inlet, and exhaust air out of the room with the point of discharge so located as not to contaminate air inlets of any other rooms or any structures;

(iii) chlorine room air entryways shall be through wall louvers near the ceiling;

(iv) chlorine room air entryway louvers and air exit-way louvers (e.g., on outside faceplate of any floor level exhaust fan) shall have air-tight closure;

(iv) separate switches for the chlorine room fans and lights shall be outside of the chlorine room near the entrance to the room, and shall be protected from vandalism; and

Guidance: For chlorinators which lack proper security, switches may be located just inside the door. A signal light indicating fan operation shall be provided at each entrance when the fan can be controlled from more than one point.

(v) vents from feeders and storage discharge above grade to the outside atmosphere.

(f) Feeder Vent Line.

The vent hose from the feeder shall discharge to the outside atmosphere above grade at a point least susceptible to vandalism and shall have the end covered with a No. 14 mesh non-corrodible screen.

(g) Housing.

Adequate housing shall be provided for the chlorination equipment and for storing the chlorine (see R309-520-10(1)(l) above).

(h) Housing at Water Treatment Plants.

A separate room, referred to as the chlorine room, for chlorine cylinders and feed equipment, shall be provided at all water treatment plants. Chlorine gas feed and storage shall be enclosed in the chlorine room and separated from other operating areas. The chlorine room shall have:

(i) shatter resistant inspection window(s) installed in an interior wall and preferably located so that an operator may read the weighing scales without entering the chlorine room,

(ii) construction such that all openings between the chlorine room and the remainder of the plant are sealed, and

(iii) outward-opening doors equipped with panic bars to facilitate a means of easy and rapid exit to the building exterior.

(iv) floor drains shall be discouraged but, where provided, these floor drains shall discharge to the outside of the building and shall not be connected to other internal or external drain systems.

Guidance: The room location shall be on the prevailing downwind side of the building away from entrances, windows, louvers, walkways, etc.

(i) Cylinder Security.

Full and empty cylinders of liquefied chlorine gas and ammonia gas shall be stored in rooms separate from each other, and shall be:

(i) isolated from operating areas;

(ii) restrained in position to prevent upset from accidental bumping, seismic event or other such circumstance;

(iii) stored in areas not in direct sunlight or not exposed to excessive heat.

(j) Feed Line Routing.

Chlorine feed lines shall not carry pressurized chlorine gas beyond the chlorinator room. Only vacuum lines may be routed to other portions of the building outside the chlorine room. Any openings for these lines must be adequately sealed.

(k) Weighing Scales.

Scales shall be provided for determining chlorine cylinder weight. Scales shall be of a corrosion resistant material and shall be placed in a location remote from any moisture. Scales shall be accurate enough to indicate loss of weight to the nearest one pound for 150 pound cylinders and to the nearest 10 pounds for one ton cylinders.

(l) Pressure Gauges.

Pressure gauges shall be provided on the inlet and outlet of each chlorine injector. Water pressures at the inlet and outlet of each chlorine injector shall be accurately measured. The preferred location is on the water feed line immediately before the inlet of the chlorine injector and at a point on the water main just ahead of chlorine injection. These locations shall give accurate pressure readings while not being subjected to corrosive chlorinated water.

Guidance: In lieu of gauges located directly at risk of corrosion in the chlorinated solution, the inlet pressure may be gauged on the injector make-up waterline immediately ahead of chlorine entrainment and the outlet pressure may be gauged in the treated water flow immediately upstream of the injectors

before the flow has been dosed with the corrosive hypochlorite solution (i.e., said measured pressure is assumed to be equivalent to the pressure immediately downstream of the injector).

(m) Injector Protection.

A suitable screen to prevent small debris from clogging a chlorine injector shall be provided on the water feed line. Provision for flushing of the screen is required.

(n) Chlorine Vent Line Protection.

A non-corrodible fine mesh (No. 14 or finer) screen shall be placed over the discharge ends of all vent lines. All vent lines shall discharge to the outside atmosphere above grade and at locations least susceptible to vandalism.

(o) Gas Masks.

(i) Respiratory protection equipment, meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) shall be available where chlorine gas in one-ton cylinders is handled, and shall be stored at a convenient location, but not inside any room where chlorine is used or stored. The units shall use compressed air, have at least a 30 minute capacity, and be compatible with units used by the fire department responsible for the plant.

(ii) Where smaller chlorine cylinders are used, suitable gas masks must be provided.

(p) Chlorine Leak Detection and Repair.

A bottle of Ammonium Hydroxide, 56% ammonia solution, shall be available for chlorine leak detection; where ton containers are used, a leak repair kit approved by the Chlorine Institute shall be provided. Continuous chlorine leak detection equipment is recommended. Where a leak detector is provided, it shall be equipped with both an audible alarm and a warning light.

(3) Additional Requirement for Hypochlorite Systems.

Disinfection by free chlorine shall be accomplished with stock hypochlorite solutions, hypochlorite solution produced by an on-site generator, or hypochlorite solutions prepared from hypochlorite tablets.

Guidance: Non-NSF-certified, over-the-counter household bleach is not approved for "normal" use in drinking water principally because of contaminant trace metals in these products.

(a) Concentrated Sodium Hypochlorite Solutions.

(i) The concentrated sodium hypochlorite solutions used for drinking water treatment shall be certified as meeting the ANSI/NSF Standard 60.

(ii) Emergency eyewash stations or showers shall be provided at all hypochlorite installations where concentrated (e.g., above 5.25% strength) hypochlorite solutions are handled for dilution by operators or other personnel.

Guidance: Where concentrated solutions of hypochlorite are used directly for water treatment (e.g., many small systems take suction for a diaphragm chemical feeder pump directly from carboys of concentrated hypochlorite solution), only eye wash devices are required although deluge showers are recommended.

(iii) The storage and injection areas shall be designed to minimize the decay of the strength of the concentrated hypochlorite solution over time, such as minimize excessive heat or direct sunlight.

Guidance: The strength of the concentrated hypochlorite solution decreases over time, especially during unfavorable temperature conditions. This affects the dosage needed to achieve effective disinfection. The operator shall keep records of the delivery date of the stock solution, and avoid direct sunlight or heat in the stock solution storage area.

(b) On-Site Hypochlorite Solutions Generation.

The on-site hypochlorite generation systems used for drinking water treatment shall be certified as meeting the NSF/ANSI Standard 61. Manufacturer recommendations for safety with respect to equipment electrical power and other considerations for the ANSI/NSF Standard 61 certified on-site chlorine generation system shall be followed.

Guidance: The on-site generation systems typically produce dilute (e.g. 0.8% as Cl_2***) solutions of sodium hypochlorite. They generally consist of (i) a potable water supply, (ii) ion exchange cartridges or cylinders for water supply water softening, (iii) a granular sodium chloride vat for passive dissolution of sodium chloride into a saturated sodium chloride brine, (iv) a transfer pump at the vat to deliver concentrated sodium chloride brine to the electrolytic chlorine generation unit, and (v) on-site storage vessels for the dilute hypochlorite solution from the electrolytic chlorine generation unit. The electrolytic cell in on-site chlorine generation systems typically has considerable power input which may pose peculiar operator hazards.***

(c) Calcium Hypochlorite.

(i) The calcium hypochlorite tablets, granules, and powder forms, used for drinking water treatment shall be certified as meeting ANSI/NSF Standard 60.

Guidance: The calcium hypochlorite systems typically consist of an eroder chamber that is filled with tablets with once-through or recirculating dissolution water, and a below-unit holding tank for the resultant dilute (e.g., 0.1%, as Cl_2) solution of calcium hypochlorite tablets.

(ii) The calcium hypochlorite dissolution systems for drinking water treatment shall be certified as meeting the ANSI/NSF Standard 61. The Director may grant an exception to this requirement on a case by case basis.

(iii) The design shall allow the calcium hypochlorite tablets to be stored in accordance with safety guidelines by the vendor or manufacturer, for example, in their original containers in a cool, dry, well-ventilated area. The calcium hypochlorite tablets shall not be stored near combustible materials and acids to avoid fire or the release of toxic gases.

Guidance: Addition of undissolved hypochlorite tablets directly to drinking water is not an appropriate, ongoing practice.

Guidance: It is recommended that, before selecting the hypochlorite tablet disinfection system, the solubility of calcium hypochlorite tablets in water, water temperature, water hardness, and other water quality factors shall be taken into consideration. Calcium hypochlorite tablet dissolution systems shall not be predicated on production of near-saturated calcium hypochlorite solutions. Slight variations in water temperature or water quality may result in crystallization of calcium hypochlorite from solution with attendant diminishment of the actual concentration of hypochlorite in solution that equipment has been programmed to deliver to the treated water.

(d) Hypochlorite Feed Equipment

(i) Hypochlorite feed equipment shall generally conform with R309-525-11, Chemical Addition; with R309-525-6 for storage and safe handing; with R309-525-7 for feeder design, location, and control; with R309-525-8 for feeder appurtenances such as pumps, day tanks, bulk storage tanks, and feed lines; and R309-525-9 for make-up water supply and protection.

(ii) The hypochlorite feed equipment for drinking water treatment shall be certified meeting the ANSI/NSF Standard 61. The Director may grant an exception to this requirement on a case by case basis.

R309-520-8. Ultraviolet Light.

(1) General Requirements

This rule shall apply to the public drinking water systems that use ultraviolet (UV) disinfection for inactivation of Cryptosporidium, Giardia, and virus. The Director may reduce the requirements of monitoring and reporting on a case by case basis for the water systems that use UV as ancillary means of disinfection and do not claim credit for UV disinfection, or for water systems using UV without a SCADA system and treating less than 30 gallons per minute.

Terminology used in this rule is based on the definitions in the EPA Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule (2006 Final UVDGM).

(a) Water systems using surface water or ground water under the influence of surface water shall not use UV as the sole means of disinfection. For these types of water systems, at least one alternative primary disinfectant must be used for virus disinfection, and a secondary disinfectant shall be provided to maintain a disinfectant residual in the distribution system.

(b) The following requirements apply to the water systems that wish to receive credit for UV disinfection:

(i) The water system shall submit a UV plan which clearly identifies the dose monitoring strategy, such as the UV intensity setpoint approach, the calculated dose approach or an alternative approach.

(ii) The water system shall identify the goals for the UV facility as part of a comprehensive disinfection strategy, including target pathogens, target log inactivation, and corresponding required UV dose per Table 215-5 in R309-215-15(19)(d).

(iii) The water system shall submit a UV reactor validation report in accordance with R309-520-8(2), to the Director for review prior to obtaining approval for installation of UV facility.

(iv) The water system must demonstrate that the reactor is delivering the required UV dose using a validated dose monitoring system and continue to comply with the monitoring and reporting requirements specified in R309-215-15(19) and (20).

(2) Validation Testing

Validation testing must conform to the guidelines in Chapter 5 Validation of UV Reactors of the EPA Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule (2006 Final UVDGM).

The Director may accept a validation report that was conducted based on the 2003 draft UV Disinfection Guidance Manual on a case-by-case basis.

(a) Each model and specific configuration of UV reactor must undergo off-site, full-scale validation testing by an independent third party test facility prior to being approved for use. The validation testing shall be conducted in qualified test facilities that are deemed acceptable by NSF, EPA, or the Director.

(b) Validation testing results shall provide data, including calculations and tables or graphical plots, on dose delivery by the UV reactor under design conditions of flow rate, UV transmittance (UVT), UV intensity, lamp status, power ballast setting, as well as consideration of lamp aging and lamp fouling. The validation report shall demonstrate that the monitoring algorithm is valid over the range expected with the application. The data is used to define the dose monitoring algorithm for the UV reactor and the operating conditions that can be monitored by a utility to ensure that the UV dose required for a given pathogen inactivation credit is delivered.

(c) The UV reactor validation report shall include:

(i) Description of the reactor and validation test set-up, including general arrangement and layout drawings of the reactor and validation test piping arrangement.

(ii) Description of the methods used to empirically validate the reactor.

(iii) Description of the dose monitoring equation for the reactor to achieve the target pathogen inactivation credit and related graphical plots showing how the equation was derived from measured doses obtained through validation testing under varying test conditions.

(iv) Range of validated conditions for flow, UVT, UV dose, and lamp status.

(v) Description and rationale for selecting the challenge organism used in validation testing, and analysis to define operating dose for pathogen inactivation credit.

(vi) Tabulated data, analysis, and Quality assurance/quality control (QA/QC) measures during validation testing.

(vii) A licensed professional engineer's third party oversight certification indicating that the testing and data analyses in the validation report are conducted in a technically sound manner and without bias.

(viii) The validation report shall be companied with completed Checklists 5.1 through 5.5 included in the EPA Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule (2006 Final UVDGM).

(3) Design Criteria

(a) A water system considering UV disinfection shall gather sufficient water quality data prior to design. The water samples shall be representative of the source water to be treated by the UV facility. Frequent testing may be required if significant variation or seasonal trending in water quality is expected.

(b) The following water quality parameters shall be considered in UV facility planning:

(i) UV Transmittance or UV Absorbance

(ii) Calcium

(iii) Alkalinity

(iv) Hardness

(v) Iron

(vi) Manganese

(vii) Turbidity

(viii) pH

(ix) Oxidation-Reduction Potential (ORP)

(x) Particle content and algae

(c) The design flow rate and UVT used to size the UV system shall be selected to provide the required dose at least 95 percent of the time, accounting for seasonal variations of flow and UVT combinations. Specifying a matrix of flow and UVT conditions for the UV reactors may be necessary.

(d) The water system may consider increasing the delivered dose beyond the required UV dose listed in Table 215-5 in R309-215-15(19)(d) to provide flexibility and conservatism.

(e) UV reactor inlet and outlet configurations shall meet the validated hydraulic distribution of flow conditions or be more hydraulically conservative. This can be achieved using one of the following approaches:

(i) The inlet and outlet configuration shall meet one of the conditions specified in Section 3.6.2 of the 2006 Final UVDGM.

(ii) Computational fluid dynamics (CFD)-based modeling may be used to demonstrate that the given conditions of inlet and outlet piping with the UV installation provides equal or greater dose delivery. The CFD modeling shall be conducted at the minimum and maximum values of the validated range of flow, UVT, and lamp status.

(f) The UV disinfection system shall be capable of applying the required design dose with a failed or out-of-service reactor. The design shall account for an on-line backup UV reactor or an operating scheme to apply the design dose with one reactor out of service.

(g) It shall be possible to isolate each reactor for maintenance.

(h) Signals and alarms shall be provided for the operation of the UV facility for the parameters necessary for dose monitoring algorithm, such as low UV dose, high flow rate, low UVT, UVT monitoring failure, UV sensor failure, off specification event, Ground Fault Interrupt (GFI), high water temperature, and low water level.

(i) All materials used in constructing or coating the UV reactors that come in contact with water shall be certified NSF Standard 61 - Drinking Water System Components – Health Effects.

(j) Any chemicals used in the cleaning of the UV reactor components in contact with the drinking water such as quartz sleeves shall be certified as meeting the ANSI/NSF Standard 60 – Drinking Water Treatment Chemicals – Health Effects.

(k) A flow or time delay shall be provided to permit a sufficient time for tube warm-up, per manufacturer recommendations, before water flows from the unit upon start up. The flow or time delay shall be included in the design so they do not result in excessive off specification conditions.

(l) To ensure a continuous supply of power, a backup power supply of sufficient capacity shall be provided for the UV disinfection system. If power quality problems, such as frequent power interruptions or brownouts, or remote location with unknown power quality, is anticipated, power conditioning equipment, such as uninterruptible power supply (UPS), shall be included in the design.

(m) The design shall include a redundant disinfection mechanism that will apply an approved primary disinfectant to achieve the CT or log removal/inactivation required for compliance if a UV facility is off specification or offline within a maximum response time of 15 minutes. One example of such response is to shut down the off- specification UV train and either bring a parallel UV train on line or initiate a back-up primary disinfection system within 15 minutes, so the continuous duration of an off- specification event is limited to no more than 15 minutes.

(n) UV disinfection units rated at 30 gallons per minute or less shall be certified as meeting the ANSI/NSF Standard 55, Class A, or other equivalent or more stringent validation or certification standards that are deemed acceptable by the Director.

(o) The dose monitoring approach used for UV facility must be reviewed and accepted by the Director. Typically the calculated dose approach is suitable for large systems or systems with significant flow variation, and the UV intensity setpoint approach is for small systems or systems with fixed flow rate. The dose monitoring approaches need to be consistent with the guidelines stated in the 2006 Final UVDGM.

(p) If Programmable Logic Controller (PLC) or SCADA interface is used for UV reactor's process control, the programming shall be in accordance with the validated dose monitoring algorithm and the validated conditions. The algorithm shall use inputs of flow, UV intensity sensor readings, lamps status, and/or UVT equal to or more conservative than values measured during the operation of the UV system. If the measured UVT is above the validated range, the maximum validated UVT shall be used as the input to the dose algorithm. If the measured flow rate is below the validated range, the minimum validated flow rate shall be used as the input to the dose algorithm. If the dose algorithm uses relative lamp output determined from the UV intensity sensor readings as an input, the relative lamp output shall be based on the measured UVT, even if it exceeds the maximum validated UVT.

(q) The UV reactor's PLC or microprocessor shall be programmed to record off specification events for the following conditions:

(i) Delivered UV dose less than the required dose,

(ii) Flow greater than the validated range,

(iii) UVT less than the validated range,

(iv) Lamp status outside the validated range,

(v) Failure of UV sensors, flow meters, or on-line UVT monitors used in the dose calculation. Laboratory measurements of UVT may be used temporarily in the program until the on-line UVT monitor is repaired.

(4) Operation and Maintenance

The operation and maintenance tasks and the frequency of performing them can be specific to the UV equipment installed. The water systems with approved UV installations shall follow the manufacturer's recommendation or the operation & maintenance guidelines stated in Section 6.2 through 6.5 of the *2006 Final UVDGM.*

(a) Startup testing.

(i) The UV reactor manufacturer must provide a site-specific operation and maintenance manual, which shall include the procedure for starting up and shutting down the UV treatment system.

(ii) Provide schedules and performance standards for start-up testing and initial operation. Schedules shall include anticipated start-up date and proposed testing duration. Performance standards shall reference applicable regulations and specific equipment capabilities.

(iii) Operators shall receive site-specific training on the operation of the UV disinfection system.

(b) An incident plan shall be developed to address lamp breakage and release of mercury, response to alarms, power supply interruptions, activation of standby equipment, failure of systems, etc.

(c) To verify that the UV reactors are operated within the validated limits, selected parameters shall be monitored. The routine operation and maintenance shall include the monitoring and calibration requirements listed in R309-215-15(19) and (20) and are in accordance with the monitoring and reporting protocol approved by the Director. For very small UV systems, the Director may consider granting exception to allow reduced monitoring and reporting on a case-by-case basis.

R309-520-9. Ozone.

(1) General Requirements

(a) Ozone is approved as a primary disinfectant, but is not approved as a secondary disinfectant for the distribution system because of its rapid decomposition in aqueous solution. A different disinfectant approved for secondary disinfection must be used if a minimum disinfection residual is required in the distribution system. Ozone may also be used for taste and odor control, oxidation of inorganic and organic compounds and for enhanced performance of other water treatment processes such as microflocculation and filtration. Some of the requirements of this section may not be applicable if ozone is used only for reasons other than primary disinfection.

(b) Pilot studies or bench scale studies shall be conducted for all surface waters unless there is sufficient data available from other studies performed on the same water source. The studies shall determine the initial ozone demand, the rate of ozone decay, the minimum and maximum ozone dosages for the range of water conditions for disinfection “CT” compliance, and the ozone dosage required for other desired benefits. Pilot studies or bench scale studies shall take into account the seasonal and other variations of the source water. Plans for pilot studies or bench scale studies shall be reviewed and accepted by the Director prior to commencement of the studies.

(2) Ozone Generation

(a) The ozone system shall be designed with backup capability such that required inactivation can be achieved with one generator out of service.

(b) The ozone generators shall be housed in an enclosed temperature controlled building for protection. Adequate ventilation shall be provided in the building, and be capable of providing six or more air changes per hour when needed in case of an ozone leak.

(c) The ozone generators shall be of the medium or high frequency type.

(d) The power supply units for the ozone generators shall have a backup electrical power source, normally an emergency generator, or the system shall have an alternate primary disinfection system that may be used in case of an electrical power outage.

(e) The ozone generators shall be water-cooled with a maximum increase in cooling water temperature of 10 ^{o}F (5.6 ^{o}C). If necessary, the cooling water shall be treated to minimize corrosion, scaling, and microbiological fouling of the water side of the tubes. A closed-loop cooling water system may be used to assure proper water conditions are maintained. The power supply units to the ozone generators may also be water cooled.

(f) The ozone generators shall comply with Section 3705 of Chapter 37, "Ozone Gas Generators," of the 2006 International Fire Code.

(3) Ozone Generator Feed Gas

(a) Feed gas may be air, vaporized high purity liquid oxygen, or oxygen enriched air. Oxygen may be generated on-site or delivered in bulk. Oxygen-enriched air is typically generated on-site.

(b) The design of the feed gas system must ensure that the maximum dew point of the feed gas of -76 ^{o}F (-60 ^{o}C) is not exceeded at any time.

(c) Liquid Oxygen Feed Gas Systems

(i) Liquid oxygen storage tanks shall be sized to provide a minimum of a 7-day supply to the ozone generators at the maximum operating rate.

(ii) There shall be two or more vaporizers to convert liquid oxygen to the gaseous form. Vaporizers must be capable of maintaining oxygen flow at the minimum design air temperature with one unit on standby.

(iii) Liquid oxygen storage tanks and system shall comply with Chapters 40, "Oxidizers," of the 2006 International Fire Code.

(d) Air or Oxygen Enriched Air Feed Gas Systems

(i) There shall be two or more air compressors to supply air. The capacity of the compressors shall be such that the demand during maximum ozone production and for other compressed air uses at the treatment plant can be met when the largest compressor is out of service.

(ii) Entrainment separators, refrigeration dryers, desiccant dryers, and filters shall be used as necessary to provide a sufficiently dried, dust-free, and oil-free feed gas to the ozone generators. Multiple units of this equipment shall be used so that the ozone generation is not interrupted in the event of a breakdown.

(4) Ozone Contactors

(a) An ozone contactor shall consist of two or more chambers to provide for introduction of ozone into the water and contact time. In a water treatment plant, ozone may be introduced in the raw water, or ozone may be introduced later in the process, such as to settled water after solids have been removed. An ozone contactor must be a closed vessel that is kept under less than atmospheric pressure to prevent escape of ozone gas. The materials of construction must be ozone-resistant to prevent premature failure of the contactor.

(b) Ozone gas may be injected into the water under positive pressure through bubble diffusers using porous-tube or dome diffusers. Alternatively, ozone gas may be injected into the water using side stream injection. This is where ozone gas is drawn into the side stream using negative pressure, which is generated in a pipe section with a venturi.

(c) An ozone contactor shall be designed to achieve a minimum transfer efficiency of 85 percent.

(d) Multiple sampling points shall be provided in an ozone contactor to enable sampling of treated water for purposes of determining an accurate measure of the concentration to be used in the “CT” disinfection calculation.

(e) A recommended minimum disinfection contact time is ten minutes.

(f) Ozone contactors shall have provision for cleaning, maintenance, and drainage of the contactor. Each contactor chamber shall be equipped with an access hatchway or other means of entry.

(g) An ozone contactor shall have an emergency off-gas pressure/vacuum relief system to prevent damage to the unit.

(h) A system must be provided for worker safety at the end of the ozone contactor for compliance with OSHA standards. Specifically, ozone levels in the gas space above treated water that has exited the contactor must not exceed the established OSHA 8-hour exposure limit of 0.1 ppm. This system may be an ozone residual quenching system where a chemical is used to destroy remaining ozone in the water, or this system may be a monitoring system that provides sufficient time to lower the residual ozone level in the water by natural decay to an acceptable level. Any chemical used to quench residual ozone shall comply with ANSI/NSF Standard 60.

(5) Off-Gas Destruction Units

(a) A system for treating the final off-gas from each ozone contactor must be provided in order to meet safety standards. Systems using thermal destruction or catalytic destruction may be used. At least two units shall be provided which are each capable of handling the entire off-gas flow.

(b) Exhaust blowers shall be provided in order to draw off-gas from the contactor into the destruction units.

(c) Provisions must be made to drain water from condensation in the off-gas piping and to protect the destruction units and piping from moisture and other impurities that may cause damage.

(d) The maximum allowable ozone concentration in the gas discharge from a destruction unit is 0.1 ppm by volume. Provisions may be made for temporary transient concentration spikes that may exceed this limit.

(6) Piping and Connections

(a) Because ozone is a strong oxidant, consideration shall be given to piping materials used in ozone service. Generally, only low carbon 304L and 316L stainless steel shall be used for ozone gas service.

(b) Connections on piping used for ozone service shall be welded where possible. Threaded connections shall be avoided for ozone gas piping because of their tendency to leak. Connections with meters, valves, or other equipment shall be made with flanged joints with ozone-resistant gaskets.

(c) A positive-closing 90-degree turn isolation valve, or other equivalent means, shall be provided in the piping between an ozone generator and a contactor to prevent moisture from reaching the ozone generator during shutdowns.

(7) Instrumentation and Monitoring

(a) A flow meter shall be provided to measure the flow rate of the water being treated. A temperature gauge or transmitter shall also be provided to measure the temperature of the water being treated. The pH shall also be measured to indicate changes in the water being treated.

(b) An ozone gas analyzer, a flow meter, and a temperature measurement shall be provided on the gaseous ozone feed line going to the ozone injection point.

(c) Ozone aqueous residual analyzers shall be provided to measure the ozone residual concentration in the water being treated in order to determine “CT” credit.

(d) An ozone gas analyzer shall be provided on the gas discharge of each ozone destruction unit, or combined vent gas discharge, to determine the exiting ozone concentration.

(e) Ambient ozone monitors shall be installed in the vicinity of the ozone generators, the ozone contactors, the ozone destruction units, and other areas where ozone gas may accumulate.

(f) A continuous dew point monitor shall be provided on the feed gas line to the ozone generators.

(g) Instrumentation such as pressure gauges, temperature gauges, flow meters, and power meters shall be provided as necessary to monitor the feed gas system, ozone generators, power supply units, and cooling water to protect the equipment and monitor performance.

(8) Alarms and Shutdowns

(a) An ambient ozone monitor shall be provided.

(b) The design shall include alarms and shutdowns.

(9) Safety

(a) Training shall be provided to the operators of ozone systems by the manufacturers of the ozone equipment, or other professionals with experience in ozone treatment, to promote the safe operation of the systems.

(b) Appropriate signs shall be installed around ozone and liquid oxygen equipment to warn operators, emergency responders, and others of the potential dangers.

(c) A means shall be provided, such as portable purge air blowers and portable monitors, to reduce residual ozone levels in an ozone contactor or other equipment to safe levels prior to entry for repair, maintenance, or emergency.

(10) Operation and Maintenance

(a) An ambient ozone monitor shall activate an alarm when the ozone level exceeds 0.1 ppm. Because the natural ozone levels can exceed 0.1 ppm under certain atmospheric conditions, it is permissible to set the alarm level at a slightly higher level to avoid nuisance alarms. Ozone generator shutdown shall occur when ambient levels exceed 0.3 ppm in the vicinity of an ozone generator or a contactor. Operators of the water treatment system may set the alarm level and the shutdown level lower at their discretion. It is recommended that an ozone ambient monitor activates a local audible alarm and/or flashing light warning, in addition to an alarm at the operator control system panel.

(b) There shall be an alarm/shutdown to prevent the dew point of the feed gas exceeding the maximum of -76 ^{o}F (-60 ^{o}C).

(c) Alarms and shutdowns shall be programmed based on the pressure gauges, temperature gauges, flow meters, and power meters, to protect the feed gas system, ozone generators, power supply units, and cooling water system.

R309-520-10. Chlorine Dioxide.

The public water systems must take into consideration that chlorine dioxide and its byproducts may have similar effects as chloramines and the impact on sensitive population. Chlorine dioxide shall not be intentionally used as a secondary disinfectant. The water system must monitor the chlorine dioxide residuals and byproducts in the distribution system. If chlorine dioxide residual enters the distribution system and may results in impact on sensitive population, the public water system shall notify the public of the change and/or the schedule for the change, particularly notification to sensitive populations such as hospitals and kidney dialysis facilities serving dialysis patients and fisheries.

(1) Pre-design Proposal

Proposals for the use of chlorine dioxide shall be discussed with the Division prior to the preparation of final plans and specifications. A water system must submit a detailed written proposal to the Director for review, including:

(a) The make, model, and specifications for proposed chlorine dioxide generator

(b) References of other U.S. potable water installations of the proposed unit

(c) Information on the operational and maintenance training program

(d) The expected total applied dosage of chlorine dioxide and other disinfectants as well as the points of application for all disinfectants and the type and amount of residuals and by-products expected in the distribution system

Guidance: It is recommended that the plans, specifications, operating procedures, and emergency response plans be reviewed by a certified safety consultant. Individuals which meet these requirements shall maintain and supervise safety programs and procedures.

(2) Chlorine dioxide generators

(a) Chlorine dioxide generation shall be designed to be efficient compared to industry standard, and production of excess chlorine shall be minimized.

Guidance: Concentrations of chlorine dioxide and chlorite in the plant effluent need to be considered in design and operation to avoid exceeding the MRDL and MCL respectively.

Guidance: Typically a well run generator can operate at more than 95% yield ($[ClO_2]/ \{[ClO_2] + [ClO_2^-] + 67.45/83.45[ClO_3^-]\}$). Maximizing yield will minimize chlorite demand and the possibility of exceeding the chlorite MCL. Discharge of free chlorine from the generator can typically be limited to less than 2% by weight. Free chlorine can contribute to DBP formation.

(b) The generator shall not produce a solution with chlorine dioxide concentration more than 6,000 mg/L to minimize the explosion hazard.

(c) The design shall include capability to measure concentrations of chlorine dioxide, chlorite, chlorate, and free chlorine of the solution leaving the generator.

(d) The chlorine dioxide generator shall be equipped with a chlorine dioxide analyzer to measure the strength of the solution leaving the generator.

(e) Generators which use solid chlorite will not be allowed.

(3) Chlorine Dioxide Feed and Storage System

(a) Chlorine Dioxide Feed system.

(i) Use fiberglass reinforced vinyl ester plastic (FRP) or high density linear polyethylene (HDLPE) tanks with no insulation.

(ii) If centrifugal pumps are used, provide Teflon packing material. Pump motors must be totally enclosed, fan-cooled, equipped with permanently sealed bearings, and equipped with double mechanical seals or other means to prevent leakage.

(iii) Provide chlorinated PVC, vinyl ester or Teflon piping material. Do not use carbon steel or stainless steel piping systems.

(iv) Provide glass view ports for the reactor if it is not made of transparent material.

(v) Provide flow monitoring on all chemical feed lines, dilution water lines, and chlorine dioxide solution lines.

(vi) Provide a means to verify calibrated feed flow to each application feed point.

(vii) Control air contact with chlorine dioxide solution to limit potential for explosive concentrations building up within the feed facility.

(viii) All chlorite solutions shall have concentrations less than 30%. Higher strength solutions are susceptible to crystallization and stratification.

(b) Chlorine Dioxide Storage and Operating Area. The following requirements apply to the chlorite storage and chlorine dioxide day tank area.

(i) The chlorine dioxide facility shall be physically located in a separate room from other water treatment plant operating areas.

(ii) The chlorine dioxide area shall have a ventilation system separate from other operating areas.

(iii) Provision shall be made to ventilate the chlorine dioxide facility area and maintain the ambient air chlorine dioxide concentrations below the Permissible Exposure Limit (PEL).

(A) The ventilating fan(s) take suction near the floor, as far as practical from the door and air inlet, with the point of discharge so located as not to contaminate air inlets of any rooms or structures.

(B) Air inlets are provided near the ceiling.

(C) Air inlets and outlets shall be louvered.

(D) Separate switches for the fans are outside and near the entrance of the facility.

Guidance: Chlorine dioxide has a permissible exposure limit (PEL) in air based on 8 hour work day of 0.1 ppm and a short term exposure limit (STEL) of 0.3 ppm. The odor threshold of chlorine dioxide is about 0.1 ppm. Special measures are needed to protect treatment plant personnel.

(iv) The area housing chlorine dioxide facility shall be constructed of non-combustible materials such as concrete.

(v) There shall be an ambient air chlorine dioxide sensor in the vicinity of the chlorine dioxide operating area. The ambient air chlorine dioxide readouts and alarm or warning light shall be audible and visible in the operating area and on the outside of the door to the operating area. The design shall include distinguishing audible alarms that are triggered by the ambient air chlorine dioxide sensor readings.

(vi) There shall be observation windows through which the operating area can be observed from outside the room to ensure operator safety.

(vii) Manual switches to the light in the operating area shall be located outside the door to the room.

(viii) There shall be an emergency shower and eyewash outside and close to the door to the operating area.

(ix) An emergency shutoff control to shut flows to the generator shall be located outside the operating area.

(x) The design shall minimize the possibility of chlorite leaks.

(xi) The chlorite tank and chlorine dioxide solution tank shall be vented to the outdoors away from any operating areas.

(xii) Gaseous chlorine feed to the chlorine dioxide generator shall enter the chlorine dioxide facility area through lines which can only feed to vacuum.

(xiii) The floor of the chlorine dioxide facility area shall slope to a sump.

(xiv) There shall not be any open drains in the chlorine dioxide operating area.

(xv) Provide secondary containments with sumps for chlorine dioxide storage, and chlorine dioxide solutions which can hold the entire volume of these vessels. This containment shall prevent these solutions from entering the rest of the operating area.

(xvi) Provide wash-down water within the operating area.

(xvii) The operating area shall be designed to avoid direct exposure to sunlight, UV light, or excessive heat.

(4) Other Design Criteria

(a) Provide secondary containment, a sump, wash-down water, and a shower and eyewash at the bulk delivery transfer point.

(b) Finished water shall be used for chlorine dioxide generation.

(c) The finished water line to the chlorine dioxide generator shall be protected with a high hazard assembly.

(d) Provide a water supply near the storage and handling area for cleanup.

(e) The parts of the chlorine dioxide system in contact with the strong oxidizing or acid solutions shall be of inert material.

(f) The design shall provide the capability to shut off the chlorine dioxide operation remotely, i.e., from a location that is outside of the chlorine dioxide operating area.

(5) Operation and Maintenance

(a) Do not store or handle combustible or reactive materials, such as acids, reduced metals, or organic material, in the chlorine dioxide operating area.

(b) Store chemicals in clean, closed, non-translucent containers.

(c) Personal protective equipment and first aid kits shall be stored at a nearby location that is outside the chlorine dioxide facility area.

(d) The temperature of the chlorine dioxide operating area shall be maintained between 60 and 100 °F.

(e) After delivery allow chlorite solutions to equalize with the ambient temperature of the operating area to avoid stratification.

(f) The Operating and Maintenance manual shall include operator safety and emergency response procedures. Personnel shall have ongoing training for operator safety and emergency response procedures.

(g) All wastes shall be disposed of in accordance to any existing solid and hazardous waste regulations.

(h) The operating area shall be inspected daily for chlorite spills and solid chlorite buildup. The daily inspections shall be logged.

(i) Chlorite leaks and solid chlorite buildup shall be cleaned up and disposed of immediately.

(j) Solid chlorite shall be washed down before removal.

Guidance: Solid chlorite is an explosion hazard. Solid chlorite shall be handled with care.

(k) The ventilation system in the chlorine dioxide facility area shall be operated to maintain the ambient air chlorine dioxide concentrations below the Permissible Exposure Limit (PEL).

(l) Audible alarms shall be programmed to alert water treatment plant personnel when the ambient air chlorine dioxide sensor in the vicinity of the chlorine dioxide operating area detects the chlorine dioxide concentration above the Permissible Exposure Limit (PEL) and the Short Term Exposure Limit (STEL).

R309-520-11. Chloramines.

Proposals for the use of Chloramines as a disinfectant shall be discussed with the Division prior to the preparation of final plans and specifications.

Guidance: Chloramines are a much weaker oxidant than free chlorine, ozone or chlorine dioxide and therefore the "CT" values for inactivation of Giardia cysts by chloramines are extremely high and may not be achievable for some systems. Chloramines may be utilized only for secondary disinfection, as necessary to maintain required disinfectant residual concentrations in water entering, or throughout, the distribution system. Chlorine may be added prior to ammonia in producing chloramines, or ammonia prior to chlorine, or even ammonia and chlorine added concurrently. The order of application of chlorine and ammonia to form chloramines is important and source waters must be evaluated to determine which method is most effective.

KEY: drinking water, primary disinfectants, secondary disinfectants, operation and maintenance
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