104. Ultraviolet Disinfection

104.1 General

Ultraviolet light produced by UV lamps has been shown to be an effective disinfectant. The lamps can be low-pressure (LP) with a wavelength between 250-270 nm or medium-pressure (MP) with a polychromatic spectrum.

The UV system should monitor the disinfection process through the intensity setpoint method or the calculated dose method.

104.2 Validation

a. UV reactors should have undergone third party biodosimetry-based validation established under the *Uniform Protocol for Wastewater UV Validation Applications*, or a similar protocol, prior to being approved for use.

b. The specific model proposed for installation should be accompanied by a validation report which identifies the range of conditions under which the reactor has been validated.

104.3 Pretreatment

a. In order to prevent particulate matter from shielding bacteria from the UV light, filtration should be provided prior to the UV disinfection unit.

b. Additional pretreatment may be required if the total suspended solids concentration to the UV unit is greater than 30 mg/L at any time.

c. Additional pretreatment may be required if the iron concentration is greater than 0.3 mg/L.

104.3 Ultraviolet Disinfection Unit

104.31 General Design Considerations

a. The system components should not be adversely affected by the normal operating environment including vibration, shock, climate, and recommended cleaning procedures.

b. Ambient temperature should be considered when designing the ballast cooling and electrical components.

c. The system or component should be designed to be accessible for cleaning and replacement of the lamp jackets and sensor window/lens that are provided on the systems.

d. The maximum water depth in the chamber, measured from the tube surface to the chamber wall, should not exceed 3 inches; or the height of the flow above the top row of UV lamps should not exceed 3 inches and should be controlled by a weir or flap gate to prevent air exposure to the quartz sleeve.

Should this be 5 cm?

e. The system should be designed based on the maximum suspended solids concentration, minimum UV transmittance and peak hourly flow rate.

f. Materials

(1) All materials exposed to UV radiation should be formulated to resist deterioration and should not impart undesirable odor, color, and/or toxic chemicals to the water upon irradiation.

(2) Systems and/or components should be constructed of material suitable to withstand temperatures generated during sustained periods when the unit is not in use.

(3) Reactor walls should be consistent with the manufacturer's recommendations and the upstream and downstream sections of the UV reactor should be light tight and water tight to prevent external runoff from entering the reactor train.

104.32 Arrangement of Units

104.321 Number of Units

a. A UV installation should consist of two or more trains with each train consisting of two or more reactors in series.

b. The combined capacity of all trains should be capable of adequately disinfecting the peak hourly flow with the largest unit out of service.

c. If only one reactor train is provided, auxiliary disinfection, such as chlorination, should be provided.

d. The reactor trains should be able to be isolated during maintenance and have enough spacing between reactors to allow for adequate maintenance.

104.322 Inlets and Outlets

a. The hydraulic conditions in the UV facility should result in a UV dose delivery that is equal to or greater than the UV dose delivered when the UV reactor was validated. There are three alternatives for meeting this condition:

(1) The length of unobstructed straight pipe upstream of each UV reactor at the UV facility is the length of straight pipe

What about open channel? Should we use channel width for pipe diameter for UV?

used in the validation testing plus a minimum of five (5) pipe diameters;

(2) Inlet and outlet configurations at the UV facility match those used during validation for at least ten pipe diameters upstream and five pipe diameters downstream of the reactor; or

(3) Velocity of the water measured at evenly spaced points through a given cross-section of the flow upstream and downstream of the reactor is within 20 percent of the theoretical velocity with both the validation test stand and the UV facility. The theoretical velocity is defined as the flow rate divided by the cross-sectional area. The velocity may be measured using pitot tubes.

b. The piping system should be as simple as possible, specifically designed to promote plug flow conditions within the irradiation zone.

c. Sufficient distance to the inlet approach should be provided so that a uniform velocity upstream of the first reactor in a reactor train is established.

d. Each reactor train should be identically designed.

e. Flow distribution should be equal across the operating reactor trains. Automatic valves should adjust position to achieve this.

f. The outlet conditions should ensure the hydraulics in the last reactor are not adversely affected by any control devices or pipefittings.

104.4 Lamps

A lamp output of 50% should be used for design unless an age factor corresponding to the replacement frequency has been established by the manufacturer, verified by third party testing and approved by DEP.

104.5 Sleeves

a. The UV tubes should be jacketed so that a proper operating tube temperature is maintained.

b. The jacket should be of quartz or high silica glass with similar optical characteristics.

c. The unit should be designed with a transmittance value of 80% through the sleeve for automatic mechanical, chemical, or manually cleaned systems. A higher value with appropriate third-party verification may be approved by DEP.

104.6 Transmittance

The effluent should have a transmittance of not less than 65% at a wavelength of 254 nm at a distance of 1 cm.

104.7 Dosage

a. At peak hourly flow, the design UV dose should be at least 40 mJ/cm^2 or the dosage necessary to achieve a 4-log inactivation of *E. coli* as established by the validation report, whichever is higher. These dosages should be applied after adjustments for maximum tube fouling, lamp output reduction after 8,760 hours of operation, and other energy absorption losses.

b. The design UV dose should be able to be applied with one unit or train out of service.

104.8 Operations, Safety and Alarm Systems

104.81 Operations and Monitoring

a. An accurately calibrated UV intensity meter, properly filtered to restrict its sensitivity to the point of the disinfection spectrum, should be installed in the wall of the disinfection chamber at the point of greatest water depth from the tube or tubes.

b. If the lamps have variable output power, or individual banks may be turned on and off, at least one UV intensity meter per bank should be installed.

c. The continuous monitoring of the following should be recorded and displayed. This information should be available in a visual display as well as a historical record.

- Flowrate,
- Turbidity,
- UV intensity,
- UV transmittance,
- Water level relative to the UV lamps,
- Lamp hours of operation,
- Operational UV dose and
- All alarms

d. There should be an operator interface provided for operator adjustment of all reactors, set points, and other control logic.

Not design standards, but can be used as permit conditions.

e. Monthly verification of the UV intensity probes should be conducted with the locations of the on-line intensity probes and reference probe in the same locations.

f. The manufacturers' recommendations should be used to calibrate the turbidity and UV transmittance monitoring equipment. Any on-line UV transmittance monitoring should be verified with grab samples on a weekly basis.

104.82 Safety

a. GFCI circuitry should be provided.

b. To ensure the hot surface of the reactor does not result in a skin burn, a temperature sensor should be installed so that if the temperature of the water exceeds a limit determined by the manufacturer, the UV reactor train should be immediately shutdown and a redundant reactor brought online.

c. Each electrical control panel shall have an emergency shutdown push button.

d. Each lamp connection in the quartz sleeve should have a humidity sensor, which may indicate that a quartz sleeve has been damaged. The reactor should immediately shut down and close the isolation valves.

104.83 Alarm Systems

a. To ensure that appropriate UV dose levels are maintained, a warning alarm should be installed to ensure prompt replacement of a burned-out-tube.

b. Annunciator panel to indicate alarm conditions should include the following:

- High and low water levels in the reactor train;
- Failure of all automatically operated valves;
- Individual, adjacent, and multiple lamp failure;
- Low UV intensity;
- Low UV transmittance;
- Low operational UV dose;
- High turbidity; and
- GFCI failure;
- Sensor failure
- High and low flow in the reactor train
- High water temperature
- Lamp end humidity

104.9 Electrical Controls

a. The unit should have an automatic flow control device, accurate within the expected range of operating flows or pressures, so that the maximum design flow rate of the unit is not exceeded.

b. The UV system should have an online UV transmittance monitor for continuous monitoring of the water transmittance.

c. The UV disinfection system should be installed with standby power and a looped per-distribution system.

d. Two or more power-distribution panels should be used to divide like disinfection system components of the same type to prevent common mode failure.

e. Control panel visual displays should be installed for all of the following:

- Status of each UV reactor on/off
- Status of each UV lamp on/off
- UV intensity of each monitored lamp
- Lamp age, in hours of each lamp
- Cumulative number of reactor on/off cycles
- Reactor power set point (if variable power input)
- Dose or log inactivation set point
- Flowrate
- Water level in the UV reactor trains
- GFI
- UV transmittance

f. A Programmable Logic Controllers (PLC) or microprocessor, programmed to meet the treatment requirements, should be provided for each reactor train.

g. A means of reprogramming the reactors should also be provided. An available Ethernet port should be located in each panel to allow a laptop to be connected

h. Both automatic and manual controls should be installed to allow independent operation of each reactor.

i. The plant SCADA system shall transfer the following information to each UV reactor panel so that trains may communicate for coordination:

- Status of each UV reactor (on/off)
- Select next UV reactor to be powered on in event of a failure
- Position status of upstream and downstream valve
- Setpoint for each upstream and downstream valve

If a SCADA system is not available, the UV reactor system shall have a Master Panel installed to coordinate operation and select the rotation of online and offline trains.

j. The SCADA system or Master Panel shall determine the valve position to ensure an even flow distribution.

k. The control panel should have a remote-local-off switch on either the touchscreen or a physical switch on the panel to allow the UV reactor train to be operated locally for maintenance or remotely by the SCADA or Master Panel. The normal position should be Remote so that the train may be shut down or brought online in the event of a train failure.

l. An Uninterruptible Power Supply (UPS) or other similar equipment with electrical surge protection should be provided for each PLC or microprocessor to retain program memory (process control program, last known set points, and measured process/equipment status) through a power loss.

m. All designs should include a “high flow” mode with a program that will recognize flow above the diurnal peak flow. All equipment and controls should be designed to accommodate this high flow mode and to optimize the treatment processes. A description of this control logic should be included in the Design Engineer’s Report and O & M Manual.

n. The UV system or component should be provided with a visual means to verify electrical operation of lamps. The unit must protect the operator against electrical shock or excessive ultraviolet energy.

o. A flow diversion valve or automatic shut-off valve should be installed to permit flow into the system only when at least the minimum ultraviolet dosage is applied. When power is not being supplied to the unit, the valve should be in a closed (fail-safe) position which prevents the flow of water into the system. Provisions should be available for any disinfection of flow during UV disinfection system failure.

p. The automatic shut-off valve should be installed downstream so that when closed, the train remains fully flooded. A train should not be brought online if not fully flooded to prevent damage to the lamps and quartz sleeves. The upstream valve should be normally open and only close for isolation and drainage during maintenance.