

SECTION 44 44 73
ULTRAVIOLET DISINFECTION EQUIPMENT FOR WASTEWATER

EQUIPMENT AND COMPONENT NUMBER(S)

PDC-3313: UV Reactor 1 Power Control Panel.
PDC-3413: UV Reactor 2 Power Control Panel.
PDC-3513: UV Reactor 3 Power Control Panel.
UV-3313: UV Reactor 1.
UV-3413: UV Reactor 2.
UV-3513: UV Reactor 3.
AE/AT 3381: UV Transmittance Sensor.

PART 1 GENERAL

1.01 SUMMARY

- A. The Work of this section includes design, fabrication, factory testing, delivery, installation, and onsite services during construction and commissioning of a pressurized closed-vessel ultraviolet (UV) disinfection system complete with accessories necessary for an operating system.
- B. Unit Responsibility: The Work requires UV disinfection system, complete with accessories and control equipment, be end product of one responsible system supplier. Supplier shall furnish components and accessories of the system to enhance compatibility, ease of operation and maintenance, and to place equipment in operation in conformance with performance, features, and functions specified.
- C. UV Supplier Scope of Supply:
 - 1. Furnish UV disinfection system complete with:
 - a. Validated UV reactors.
 - b. UV reactor power control panel (PCP).
 - c. Power supply line filters, if required.
 - d. Transient voltage surge suppressors, if required.
 - e. Lamp power ballasts.
 - f. Power supply transformers, if required.
 - g. Lamps.
 - h. Quartz sleeves.
 - i. Calibrated duty and reference UV intensity sensors.
 - j. Temperature switch for the protection of UV system.
 - k. Automatic cleaning system.
 - l. Consumables required for startup, functional and performance testing.
 - m. Cleaning chemicals, if applicable.

- n. Electrical and control wiring within UV reactor.
- o. UV transmittance (UVT) analyzer.
- p. Programming of operator interface terminal (OIT) and PLC.
- q. Extra materials for expected normal operation during first year.
- r. Shipping components to Site.
- s. Manufacturer's installation and O&M manuals.
- t. Manufacturer's Field Services, including but not limited to, equipment installation supervision, startup, performance testing, and training services; performance guarantees and warranties; and anything else that may be required to ensure a complete UV System, as specified herein.

D. Contractor Scope of Supply:

1. Provide materials, equipment, and appurtenances not supplied as part of UV Supplier scope of supply, but required for complete, functional, and operational UV System including, but not limited to:
 - a. Unloading and storing UV equipment at Site in accordance with manufacturer's instructions.
 - b. Structural supports required to install UV reactors that are not supplied by UV Supplier; for example pipe supports for upstream and downstream piping whether it supports UV reactor or not. Provide structural calculations to UV Supplier and Contracting Officer.
 - c. Hardware, fasteners, gaskets, anchor bolts, nuts, plates, and angles necessary for installation of UV System.
 - d. Air relief valves, drain valves, cooling water valves (if necessary), and associated piping necessary for proper operation of UV reactor.
 - e. Conduit, fittings, supports, hubs, wiring including wire terminations and terminators for installation of UV reactors, PCPs, instruments, analyzers, devices, and OITs supplied as part of UV System.
 - f. Equipment supports, U-bolts, and hardware to install ancillary equipment supplied by UV Supplier. Ancillary equipment shall include UVT analyzers, control and power panels, and other equipment needed for a fully functional and validated UV system.
 - g. Temporary equipment and piping for bioassay spot-check commissioning and performance testing shall be provided by Contractor and coordinated with UV Supplier. Water supply shall be potable water or permeate. Effluent flow from testing shall be discharged to the Equalization Basins. An injection port shall be provided on the temporary piping for testing.

- h. Onsite assistance to UV Supplier during functional testing and performance testing as defined in Article Field Quality Control.
- i. Refer to UV Supplier's Shop Drawings for additional requirements.

1.02 REFERENCES

- A. The following is a list of standards that may be referenced in this section:
 - 1. American National Standards Institute (ANSI).
 - 2. Institute of Electrical and Electronics Engineers, Inc. (IEEE): 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
 - 3. National Electrical Manufacturers Association (NEMA).
 - 4. National Fire Protection Association (NFPA): 70, National Electric Code (NEC).
 - 5. National Water Research Institute (NWRI), Ultraviolet Disinfection – Guidelines for Drinking Water and Water Reuse, 2012.
 - 6. UL: 508A.
 - 7. U.S. Environmental Protection Agency (USEPA): Ultraviolet Disinfection Guidance Manual (UVDGM).
- B. Refer to Section 01 33 23, Submittal Procedures, for submittal requirements and procedures to be provided under this Contract by the UV Supplier.
- C. Refer to Section 01 88 15, Anchorage and Bracing, for anchorage and bracing requirements.
- D. Refer to the following sections for electrical requirements:
 - 1. Section 26 05 02, Basic Electrical Requirements.
 - 2. Section 26 05 04, Basic Electrical Materials and Methods.
 - 3. Section 26 05 10, Network Communication Systems.
 - 4. Section 26 05 26, Grounding and Bonding for Electrical Systems.
 - 5. Section 26 43 00, Surge Protective Devices.

1.03 DEFINITIONS

- A. Bioassay: A biological test used to assess the effectiveness of UV disinfection for the inactivation of microorganisms.
- B. End of Lamp Life Aging Factor (ELAF): The reduction in available UV output at the end of UV lamp life as compared to a new UV lamp, after the appropriate burn-in period.
- C. Intensity: Power passing through a unit area perpendicular to direction of propagation. Describes magnitude of UV light measured by UV sensors in a

reactor and with a radiometer in bench-scale UV experiments. Units of intensity are milliwatts per square centimeter (mW/cm^2). The term “ S/S_0 ” indicates ratio of the measured intensity at a point in time to the measured intensity with a new lamp (after 100-hour burn-in) and new, clean sleeve, measured UVT greater than design UVT, and full lamp power.

- D. Head Loss: Loss of energy caused by friction or turbulence induced by appurtenances in pipes, equipment, and open channels.
- E. LPHO: Low pressure high output.
- F. Operator Interface Terminal (OIT): Graphical interface between each UV reactor and operator (user), mounted on a control panel.
- G. OIU: Operator Interface Unit. Graphical interface between each UV reactor and operator (user).
- H. Power Control Panel (PCP): Also referred to as Power Distribution Center (PDC). The UV vessels shall be controlled by the PCP, which will communicate with the plant PLC which shall include PLC integration of all signals and logic to provide fully automated control of the UV system.
- I. QSFF: Quartz sleeve fouling factor.
- J. Reduction Equivalent Dose (RED): UV dose derived by entering the log inactivation measured during full-scale reactor validation testing into UV dose-response curve that was derived through collimated beam testing. RED values are always specific to the challenge microorganism used during experimental testing and validation test conditions for full-scale reactor testing. Indicates dose necessary, with full-scale UV System, to provide a level of inactivation of a specific organism (for example, MS-2 bacteriophage) equivalent to level of inactivation for the same organism achieved in a laboratory, using a collimated beam apparatus with a low pressure lamp producing UV energy at a wavelength of 254 nanometers on a water sample collected at the same time.
- K. UV Dose (Fluence): Indicates UV energy per unit area incident on a surface, typically reported in millijoules per square centimeter (mJ/cm^2). UV dose received by a waterborne organism in a reactor vessel accounts for the effects on UV intensity of the absorbance of the water, absorbance of the quartz sleeves, reflection and refraction of light from the water surface and reactor walls, and germicidal effectiveness of UV wavelengths transmitted.
- L. UV Supplier: Synonymous with UV System Manufacturer or Vendor. Responsible for specified Work of this section.

- M. UV System: Synonymous with “UV Disinfection Equipment” or “UV Disinfection System,” which includes related UV equipment, materials, and appurtenances.
- N. UV Transmittance (UVT): Indicates transmittance of ultraviolet light at a wavelength of 254 nanometers through water across a path length of 1 centimeter. UVT shall be expressed as a percentage.
- O. Validated Dose (Dval): RED divided by VF as described in the USEPA UVDGM.
- P. Validation Factor (VF): An uncertainty term that accounts for the uncertainty and bias associated with validation testing and full-scale installation as defined by the USEPA UVDGM.

1.04 SUBMITTALS

A. Action Submittals:

1. List mechanical components of UV system and complete catalogue information, descriptive literature, specifications, and identification of materials of construction, including spare parts.
2. Detailed bill of materials by model and part number. List manufacturer names, addresses, and phone numbers.
3. Detailed UV reactor information including make/model, pressure rating, flange size, headloss curve, min/max validated and allowable flow rate, min/max validated and allowable UVT, min/max RED, min/max log inactivation, reactor support requirements, quantity/location of UV lamps and intensity sensors, cooling water requirements, lamp cool-down/warm-up requirements, empty and full weight, and air-release/drain line connection details.
4. Summary of UV System control strategy including UV dose equation or calculations as a function of flow, UVT, target organism inactivation, and lamp age/sleeve fouling factors. Provide graph or table of min/max RED as a function of flow, UVT, S/So, and ballast intensity.
5. Provide summary calculations to show compliance with the minimum required UV dose MS2 RED basis at the worst-case design conditions that were used as the basis for the capital sizing of the UV system.
6. Graph of MS2 RED versus flowrate up to the maximum allowable flowrate through the reactor (independent of headloss) for UVT of 65 percent, all full power, and end of lamp life/fouled sleeves.
7. Drawings showing plan layout, cross sections, dimensions, critical clearances, and interconnections and interface requirements such as power, controls, and instrumentation. Identify separately mounted components, connections to other work, critical clearance requirements,

interconnections and interface requirements, and validated hydraulic configuration.

8. Controls:

a. Submittals as specified in Section 40 99 90, Package Control Systems, including, but not limited to:

- 1) Complete specifications, descriptive drawings, catalog cuts, and descriptive literature which shall include make and model of instrumentation and components of control system.
- 2) Complete process and instrumentation diagrams (P&IDs), network interface drawing, electrical schematic and wiring diagrams, electrical ladder diagrams, interconnection diagram showing power and control interfaces among all system components, and instrument settings.
- 3) Power control panel arrangement drawings. Include wiring and schematic diagrams, program documentation (PLC-based), network equipment, mounting, location, and communications network diagram, and I/O listing. Include panel interior and door layout Drawings, and sample operator interface screens.
- 4) Details of control and power panels including internal and external panel layouts, dimensions, access requirements, materials of construction, bill of materials, electrical schematics, and wiring diagrams. Include software and hardware component details. Provide measurements to verify lead length limitations on communication circuit cabling have not been exceeded.
- 5) Detailed description of instrumentation and control system, including list of functions monitored, controlled, and alarmed. Describe automatic shutdown features and interfaces with plant instrumentation and control system.
- 6) Control system block diagram(s) including OIT(s), Programmable Logic Controllers (PLCs), and networking. Proposed layouts and development of OIT screens for control of UV System.
- 7) Fully documented ladder logic listings, I/O printouts, and cross-referenced printouts documenting programmable controller software program.

9. Detailed description of instrumentation and control system, including list of functions monitored, controlled, and alarmed. Describe automatic shutdown features and interfaces with plant instrumentation and control system.

10. Input power voltage, frequency, and phase requirements, total system maximum power load, power quality thresholds, and ballast turndown capabilities.

11. Specifications for interconnecting cables between UV equipment, including voltage ratings, insulation type, conductor material and cable/conductor outside diameter, and maximum cable length.
12. Lamp data, including watt rating, initial lumen output, lamp aging factors, average lumens, and total mercury content.
13. Complete description of automatic lamp sleeve cleaning process and maintenance requirements.
14. Complete description of UVT analyzer; include operation and maintenance requirements necessary for compliance with EPA requirements.
15. Details of UV intensity sensors including sensor traceability and uncertainty from linearity, temperature response, spectral response, angular response, and long-term drift. Include calibration requirements necessary for compliance with USEPA UVDGM requirements.
16. Estimated power consumption (kWh), harmonics generation, and power factor for individual UV reactor at 50 percent, 75 percent, and 100 percent ballast power levels.
17. Data on harmonic filters, or active filters, if required.
18. Anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.
19. Outline Drawings for all items that are shipped loose.
20. Factory Test Results:
 - a. Submit factory test results including manufacturer's quality assurance.
 - b. Include copies of original test data collection forms.
21. Manufacturer's Field Report: Submit manufacturer's field report of inspections, tests, and observations for all items furnished under this section.
22. Test procedures for factory and field testing. Include extended checkpoint bioassay test procedures if required to demonstrate minimum and/or maximum operating conditions as specified. All bioassay test procedures, testing, and analysis shall be developed and performed by a third-party.
23. Test results, reports, and certifications.

B. Informational Submittals:

1. Validation Testing:
 - a. Detailed report with third party signature, raw data, and documentation of reactor performance validation testing per the 2006 USEPA UVDGM or 2012 NWRI guidelines.
 - b. If validation is based on UVDGM, provide completed versions of Checklists 5.1 through 5.5 of the USEPA UVDGM; checklists shall be signed and dated by UV Supplier.
2. Third-party certification of ELAF and QSFF.

3. Manufacturer's design, supporting calculations, and layout of anchor bolts.
4. Calculations for structural supports, stamped by Arizona PE.
5. Anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
6. Manufacturer's printed installation instructions.
7. List of replaceable system components along with their expected replacement frequencies, duration of life warranties, guaranteed replacement prices, and calibration frequencies. Include a list of special tools required for checking, testing, parts replacement, and maintenance.
8. Prior to delivery provide manufacturer's instructions for materials requiring special shipping, storage, or handling requirements.
9. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.
10. Factory Test Report, data sheets, and witness report.
11. Functional Test Plan: Provide a narrative of the test plan and data to be recorded and analysis to be completed, including all forms for recording data during the test. The test plan shall include, but is not limited to the testing of the delivery of the UV dosage, the lamps, the intensity sensors, the cleaning system, PDC for each of the reactors, and the instrumentation and controls for each of the reactors, and OITs. The scope of the factory test shall demonstrate that each of the individual UV systems operates as specified.
12. Functional Testing Report: Provide narrative and data summary discussing each element requiring testing, tests performed, and the results.
13. Performance Test Plan: Provide a narrative of the test plan and data to be recorded and analysis to be completed, including all forms for recording data during the test.
14. Performance Testing Report: Provide narrative and data summary discussing each element requiring testing, tests performed, and the results. This test shall be performed when the plant systems are operational and there is water available for testing. As part of the UV performance testing, power monitoring shall be conducted by the UV system manufacturer to indicate total power consumption in kW-hr, power factors, and harmonic distortions at ballast's maximum power settings. Headloss measurements shall be performed for the maximum allowable flow, average day, and minimum flow per reactor.
15. Provide fully documented, as-Built PLC and OIT programs electronically in Rockwell Automation software and PDF format.
16. Fully documented ladder logic listings, function listing for function blocks not fully documented by ladder logic listings, cross-reference listings, and operator interface configuration documentation.
17. Service records for maintenance or calibration reports for calibration performed during construction or testing activities.
18. Guaranteed replacement pricing as listed in Article Special Guarantee.

19. Manufacturer's Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers' Field Services.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Shipping:

1. Clearly identify packages as to Project, destination, and contents. Packaging shall protect equipment from damage during shipping.
2. Deliver equipment and appurtenances to designated location.
3. Polish and protect surfaces from corrosion and damage during shipment, normal handling and installation.
4. Pack equipment for shipment and protect electrical equipment from moisture damage.
5. Identify each component with durable labeling other than paper that is resistant to sunlight exposure and moisture.

B. Delivery and Storage:

1. UV Supplier representative will be available for assistance upon delivery and shall assist Contractor as follows:
 - a. Inspecting equipment upon arrival at Site to ensure equipment has been delivered in good order and that no damage has occurred during delivery.
 - b. Identification of and notification to Contractor and Contracting Officer of discrepancies between shipping lists and equipment received.

1.06 SPECIAL GUARANTEE

- A. Guarantee each item of mechanical and electrical equipment, instruments, and devices furnished under this Contract against defects including, but not limited to, the following:
 1. Defective material or workmanship of both.
 2. Leakage, breakage, or other failure which might occur under normal and proper operation of the equipment under the specified conditions.
 3. UV reactor/component failure, as defined herein, during guaranteed life.
- B. Replace each item of equipment or part thereof proving to be defective.
- C. Bear expense of replacement including, but not limited to, cost of labor, supervision, traveling, replacement parts, transportation, and shipping cost. Contractor shall coordinate and facilitate.

- D. Provide a UV system performance guarantee for a period of 1 year from Contracting Officer's final acceptance of Performance Test with the membrane filters.
- E. Guarantee life and replacement pricing for UV lamps, quartz sleeves, ballasts, and duty and reference UV intensity sensors following Contracting Officer's final acceptance of Performance Test.
 1. Replacement Pricing:
 - a. UV Supplier shall guarantee following items may be purchased at submitted guaranteed price or lower any time up to 20 years following Substantial Completion of installation. Guaranteed prices shall be adjusted by Consumer Price Index (CPI) on annual basis. Freight charges are not to be included.
 - 1) Lamp replacement prices.
 - 2) Quartz sleeve replacement prices.
 - 3) Ballast replacement prices.
 - 4) Duty sensor calibration prices.
 - 5) Reference sensor calibration prices.
 - 6) Duty sensor replacement prices.
 2. UV Lamps:
 - a. LPHO lamps shall be warranted for at least 12,000 hours, prorated after 9,000 hours prior to lamp output reaching ELAF.
 - b. If lamp fails within initial prorated period, provide replacement lamp free of charge.
 - c. If lamp fails after initial prorated period and before guaranteed life use the following formula to determine discounted price for replacement lamps:

$$\text{Lamp Price} = (\text{Lamp Operating Hours} - 9,000 \text{ hrs}) / (12,000 \text{ hrs} - 9,000 \text{ hrs}) \times \text{Guaranteed Lamp Cost.}$$
 3. Ballasts:
 - a. Warranted for 5 years, prorated after 1 year.
 - b. If ballast fails within initial prorated period, provide replacement ballast free of charge.
 - c. If ballast fails after initial prorated period and before guaranteed life, use the following formula to determine discounted price for replacement ballast:

$$\text{Ballast Price} = (\text{Ballast Operating Time} - 1 \text{ yr}) / (5 \text{ yrs} - 1 \text{ yr}) \times \text{Guaranteed Ballast Cost.}$$
 4. Quartz Sleeves:
 - a. Warranted for at least 10 years, prorated after 1 year.
 - b. If quartz sleeve fails within initial prorated period, provide replacement sleeve free of charge.

- c. If quartz sleeve fails after initial prorated period and before guaranteed life use the following formula to determine discounted price for replacement sleeve:

$$\text{Sleeve Price} = (\text{Sleeve Operating Time} - 1 \text{ yr}) / (10 \text{ yrs} - 1 \text{ yr}) \times \text{Guaranteed Sleeve Cost.}$$
- 5. UV Sensors:
 - a. Warranted for at least 5 years, prorated after 1 year.
 - b. If UV sensor fails within initial prorated period, provide replacement sensor free of charge.
 - c. If UV sensor fails after initial prorated period and before guaranteed life use the following formula to determine discounted price for replacement sensor:

$$\text{Sensor Price} = (\text{Sensor Operating Time} - 1 \text{ yr}) / (5 \text{ yrs} - 1 \text{ yr}) \times \text{Guaranteed Sensor Cost.}$$

1.07 DATA INTEGRATION WITH PLANT CONTROL SYSTEM/SCADA

- A. The UV Supplier is required to interface with and be integrated with the Plant Control System (PCS) or SCADA. The System Supplier shall assist with coordination and integration of the UV control systems into plant control by providing:
 - 1. Logistical and technical support for parallel monitoring and control of the UV control system and the PCS, including but not limited to:
 - a. Coordination between plant and UV package P&IDs.
 - b. Defining data maps to be exchanged between the UV control system and PCS.
 - c. Defining communication requirements and programming procedures to accomplish the data exchange and parallel control by the UV control system and PCS.
 - d. Export files of PLC logic, tag-names, and I/O configurations for incorporation into PCS/SCADA.
 - e. Graphic display (“screen shots”) files and functional descriptions of graphic elements.
 - 2. Testing and startup assistance.
 - 3. Scheduling and facilitating communication of the specific technical data necessary to coordinate and integrate the systems, including:
 - a. Workshops to convey and disseminate essential information between the System Supplier and Contracting Officer.
 - b. Designing UV system application software and hardware to facilitate the transfer of monitoring and control functionality and data with the PCS.
- B. Delivery: In accordance with Section 01 67 00, Product Requirements.

PART 2 PRODUCTS

2.01 MANUFACTURERS

- A. Materials, equipment, and accessories specified in this section shall be products of:
 - 1. Trojan Technologies; UVFIT Series.
 - 2. Or equal.

2.02 GENERAL SYSTEM CHARACTERISTICS

- A. UV System will be located in Facility 32, downstream of membrane permeate pumps at the Grand Canyon South Rim Wastewater Treatment Plant.
- B. Physical Characteristics:
 - 1. The UV system must fit within the UV room dimensions shown on the Drawings.
 - 2. UV System shall be comprised of the following components:
 - a. UV reactor(s) including lamps, quartz sleeves, and appurtenances.
 - b. Number of UV Reactors: As required to treat peak design flow with one unit offline.
 - c. Local Power Control Panel(s): One per reactor.
 - 1) Includes lamp ballasts, remote I/O panels, and interconnecting power and control wiring between UV reactor and local power distribution center.
 - d. UV Intensity Sensor: One per reactor.
 - e. Wiping System: Automatic mechanical.
 - f. UVT Analyzer: One.
 - 1) Capable of meeting performance requirements of the NWRI.
 - g. Local Control Panel: One control panel to handle control and sequencing of UV trains, perform functions common to UV trains, and monitor UV train status and alarms.
 - h. Power Transformers/Conditioners: If required to accommodate incoming power voltage, variations, or quality.
 - 3. Electrical assembly shall meet requirements of NFPA 70 (NEC), NEMA, and applicable local electrical codes.
 - 4. Components, including equipment, coatings and other parts of UV System shall comply with AWWA standards, unless specified otherwise.
 - 5. Terminal point connections shall be ANSI standard flanges.
 - 6. Hardware, fasteners, anchor bolts, nuts, plates, and angles shall be Type 316 stainless steel.

7. Mating flanges shall be as required in pipe schedule. Bolts and nuts shall be Type 316 stainless steel. Gaskets shall be ethylene propylene diene monomer rubber (EPDM).
8. UV reactor external material shall be welded Type 316L stainless steel, pickled, passivated, and bead-blasted for uniform external finish.
9. UV reactor internal metal parts shall be constructed of Type 316L stainless steel, pickled, and passivated.
10. ANSI Class 150 flanged inlet/outlet connections.
11. Internal nonmetallic materials shall be suitable for continuous exposure to UV light.

C. Functional Characteristics:

1. The UV reactors will be dose paced with the UVT reading upstream of the UV reactor and flow reading from the flow meter at the inlet of each UV reactor. The control programming shall have a function to allow user-entry UVT value for the dose pacing.
2. Provide a UV system complete with UV reactor(s) and Power Control Panel(s) as shown on the Drawings and as herein specified.
3. UV system must operate in a pressurized closed vessel, use high-intensity low-pressure amalgam UV lamps, electronic ballasts with multiple power settings, and incorporate an automatic sleeve wiping system for lamp sleeves and sensor sleeves/windows.

D. Performance Characteristics:

1. Provide equipment that will provide disinfection for the following flow characteristics:
 - a. Peak Equalized Flow to UV Reactors: 1.2 mgd.
 - b. Annual Average Flow to UV Reactors: 0.42 mgd.
 - c. Minimum Flow: 0.10 mgd.
2. Provide redundancy to provide disinfection for the peak design flow with one reactor offline.
3. UV System Influent Turbidity: 5 Nephelometric turbidity unit (NTU) maximum.
4. UV System Influent Temperature Range: 33 degrees F to 85 degrees F (1 degree C to 30 degrees C).
5. UV System Influent UV Transmittance (UVT) at 254 nm: 65 percent, minimum, under design conditions.

6. The UV disinfection system shall be capable of producing an effluent conforming to the following discharge permits:
 - a. Plant Effluent – Fecal Coliform: 2.2/100 mL 7 day median maximum; 23/100 mL single 30 day maximum; not to exceed 240/100 mL.
 - b. Recycled Water – Total Coliform (MPN): 2.2/100 mL 7 day median maximum; 23/100 mL single 30 day maximum; not to exceed 240/100 mL.
7. The UV system shall be designed to deliver a minimum UV dose of 80 mJ/cm^2 at peak flow, in effluent with a UV Transmittance of 65 percent at end of lamp life (EOLL) after reductions for quartz sleeve fouling. The basis for evaluating the UV dose delivered by the UV system will be the independent third party bioassay, without exception. Bioassay validation methodology to follow protocols per NWRI.
8. The UV dose will be adjusted using an end of lamp life factor of 0.5 to compensate for lamp output reduction over the time period corresponding to the manufacturer's lamp warranty. The use of a higher lamp aging factor will be considered only upon review and approval of independent third party verified data that has been collected and analyzed in accordance with protocols per NWRI.
9. The UV Dose will be adjusted using a quartz sleeve fouling factor to compensate for reduction of UV dose due to wastewater fouling during operation. If no quartz sleeve wiping system is included, a fouling factor of 0.5 shall be applied. If an automatic wiping system is included, a fouling factor of 0.8 shall be applied.
10. Independent Validation for use of a higher lamp aging factor must be submitted to the Contracting Officer for review a minimum of 15 days prior to bid.
11. The UV system shall be able to continue providing disinfection while the automatic wiping system is in operation.
12. System shall be designed to operate in an environment with ambient relative humidity of 5 percent to 90 percent and ambient air temperature of 32 degrees F to 104 degrees F (0 degree C to 40 degrees C).
13. UV system shall have been independently validated in accordance with NWRI. UV system sizing to be completely based on data collected during validation testing. No extrapolations outside tested range will be allowed.

2.03 DESIGN

A. UV Reactor:

1. Physical Characteristics:
 - a. The UV reactor shall be manufactured from Type 316L stainless steel. The UV reactor shall be pickled, passivated and bead blasted for uniform external finish.

- b. Each UV reactor shall be supplied with 12 inches (300 mm) ANSI 150-pound flanged inlet/outlet connections.
 - c. Maximum length of each UV reactor: not to exceed 95 inches.
 - d. The UV reactor is to be configured such that flow enters parallel to the lamps and exits through a flange located perpendicular to the UV lamps.
 - e. UV Lamps: Each UV reactor shall contain 32 high-intensity low-pressure amalgam lamps arranged horizontally and parallel to the direction of flow.
 - f. Each lamp shall be enclosed in an individual quartz sleeve, one end of which shall be closed and the other sealed with compressed O-rings.
 - g. Each UV reactor shall be provided with an end cap and safety switch. Power will be removed to the entire chamber when a reactor end cap is removed.
 - h. The UV reactor shall be provided with access ports for easy access to the quartz sleeves.
 - i. All access for internal reactor components, including lamps, sleeves and wiping system shall be from the same end. Designs requiring access from more than one side of the reactor are not permitted.
 - j. The UV reactor shall be installed horizontally.
 - k. Dry weight of the reactor shall not exceed 1,600 pounds (725.7 kg).
 - l. Wet weight of the reactor shall not exceed 2,200 pounds (997.9 kg). Pipe supports, if necessary, shall be supplied by others.
2. Functional Characteristics:
- a. The UV reactor shall be designed such that operating personnel at the plant can change lamps without draining the reactor.
 - b. Piping shall be designed so that the reactor remains full of water at all times during operation. Air trapped in the reactor will result in reactor shut down to avoid overheating.
 - c. UV disinfection equipment system shall be programmed, consistent with USEPA UVDGM, such that UVT greater than maximum validated UVT shall be considered equal to maximum validated UVT in the system programming and dose calculations. No extrapolation of system performance shall be allowed.
3. Performance Characteristics:
- a. The UV reactor shall be designed to handle a maximum operating pressure of 100 psig (6.8 bar) and shall be fully assembled and hydrostatically tested to 1.5 times the rated operating pressure, for at least 10 minutes without leakage, in the factory prior to shipment.
 - b. Headloss through each UV reactor shall not exceed 2 inches H₂O under peak flow conditions.

- c. Input Voltage:
 - 1) 480V ac, 60-Hz, three-phase, four-wire.
 - 2) UV System shall be capable of operating during a 30 percent voltage drop from nominal, without shutting down.
 - 3) UV system shall be capable of operating during an 8 millisecond voltage drop without shutting down.
- d. Under the NWRI UV Guidelines (2012), validation shall provide minimum pathogen inactivation requirement over full range of flows, UV dose, and water characteristics at end of lamp life and under fouled quartz sleeve conditions.
- e. Validated conditions for reactor shall include at least 5 percent UVT less than design value.
- f. Validation testing shall be based on MS 2 Bacteriophage as an indicator organism.

B. Lamps:

- 1. Physical Characteristics:
 - a. The filament will use a clamped design and be significantly rugged to withstand shock and vibration.
 - b. Lamps shall be monochromatic with minimum 90 percent of UVC output at wavelengths between 230 nm to 275 nm.
- 2. Functional Characteristics:
 - a. Lamps will be high-intensity low-pressure amalgam. The lamps will be preheated to ensure long lamp life. Lamps that are not amalgam or that are based on driving a low-pressure lamp at amperages greater than 500 milliamps will not be allowed.
 - b. Lamps shall be operated by variable output electronic ballasts from 60 percent to 100 percent of full power.
 - c. Lamps will be rated to produce zero levels of ozone.
- 3. Performance Characteristics: Electrical connections will be at one end of the lamp and have four pins, dielectrically tested for 2,500 volts. Lamps that do not have 4 pins will be considered instant-start. To be considered as an alternate, instant-start lamp systems will supply replacement spare lamps equal to 50 percent of the total number of lamps in the system.

C. Lamp End Seal and Lamp Holder:

- 1. Physical Characteristics:
 - a. The open end of the UV lamp sleeve will be sealed by a compression O-ring.
 - b. The O-ring compression is made by a sleeve nut that will require no special tools for installation or removal.

2. Functional Characteristics: None.
3. Performance Characteristics: None.

D. Lamp Quartz Sleeves:

1. Physical Characteristics:
 - a. Type 214 clear fused circular tubing.
 - b. Lamp sleeves shall be domed at one end and be accessible through the reactor service entrance.
 - c. The nominal wall thickness will be 1.5 mm.
2. Functional Characteristics: None.
3. Performance Characteristics: None.

E. Intensity Sensor:

1. Physical Characteristics:
 - a. The UV Intensity Sensor shall be located inside the reactor and contained within protective quartz sleeves.
 - b. One sensor shall be provided per reactor chamber.
2. Functional Characteristics:
 - a. The sensor will measure only the germicidal portion of the light emitted by a UV lamp. The detection system will be factory calibrated. Sensors that can be field calibrated will not be permitted.
 - b. The quartz sleeve protecting the sensor shall be wiped by a mechanical wiping system.
3. Performance Characteristics: The sensor will measure only the germicidal portion of the light emitted by a UV lamp. The detection system will be factory calibrated. Sensors that can be field calibrated will not be permitted.

F. Ballasts:

1. Physical Characteristics: Electronic ballasts shall be used to power UV lamps.
2. Functional Characteristics:
 - a. Each ballast shall supply power to and control two low-pressure amalgam lamps.
 - b. Ballasts shall have a variable operation range of 60 percent to 100 percent of full rated output.
 - c. The ballasts shall utilize a preheat circuit to ignite the lamps.
 - d. The ballasts will continue to operate without suffering damage when a short circuit is present across the ballast output terminals.
3. Performance Characteristics:
 - a. The power factor shall not be less than 94 percent between 208 Vrms to 277 Vrms at 100 percent power.

- b. The Total Harmonic Current Distortion shall be less than 5 percent.

G. Dose Pacing:

- 1. Physical Characteristics: None.
- 2. Functional Characteristics:
 - a. A dose-pacing system shall be supplied to modulate the lamp power levels based on the flow rate and UV sensor signal.
 - b. UV Transmittance value from the UVT analyzer upstream of the UV reactors shall be used. The dose pacing programming shall have an option to use the UVT value over-write with a user-defined value changeable by the user.
 - c. Flow reading values from the flow meter at the inlet of each UV reactor shall be used.
 - d. The system shall be dose-paced such that as the flow rate, water quality, and lamp conditions change, the RED (dose) is delivered while conserving power.
- 3. Performance Characteristics: None.

H. Wiping System:

- 1. Physical Characteristics:
 - a. Each UV reactor shall be equipped with an automatic on-line sleeve wiping system.
 - b. The wiping system shall be driven by a screw drive system.
- 2. Functional Characteristics:
 - a. The wiping system shall wipe both the lamp sleeves and the UV sensor sleeves/windows using an automatically initiated and controlled wiping cycle. The wiping system shall be fully operational while still providing disinfection.
 - b. Wiping cycle intervals shall be field adjustable via the operator interface. Manual wiping system control shall also be through the operator interface.
 - c. Wiper position and wiping count shall be recorded at the local PCP.
- 3. Performance Characteristics: None.

I. Drain:

- 1. Physical Characteristics:
 - a. Each reactor shall be furnished with a drain valve connection so the reactor can be dewatered for inspection or cleaning after the inlet and outlet valves are closed.
 - b. The drainpipe (supplied by Others) and valve shall be of Type 316 stainless steel construction.

2. Functional Characteristics: None.
3. Performance Characteristics: None.

J. Local UV Reactor Power Control Panels (PCPs):

1. Physical Characteristics:
 - a. One PCP shall be provided for each UV reactor.
 - b. Connected electrical load for each UV disinfection system is not to exceed 45 kVA.
 - c. Power distribution for each UV reactor shall be through the associated PCP housing all power supplies. Signal wiring interfacing the UV reactor with the PCP shall be as shown on the Drawings.
 - d. The PCP enclosure shall be Type 12, ventilated with forced air cooling suitable for indoor installation.
 - e. The PCP enclosure shall be UL or CSA approved.
 - f. The PCP shall be installed within 15 feet (4.5 m) of the UV reactor (external running cable length). Each PCP shall be provided with a lockable disconnect handle that will shut down the reactor/cabinet power when the cabinet door is opened.
 - g. PCP enclosure shall be floor mounted.
 - h. PCP enclosure dimensions shall not exceed 86 inches (2,184 mm) high by 40 inches (1,016 mm) wide by 18 inches (457 mm) deep. Weight shall not exceed 700 pounds (318 kg).
 - i. PCP shall include control power transformers for required voltages. Provide complete power distribution system for ballasts/lamps and ancillary equipment associated with each reactor. Electrical system shall comply with local electrical code requirements.
 - j. Prewire panels to maximum extent possible, requiring only field connections for power and field devices.
 - k. For communication circuits, provide cable and connectors per device manufacturer's recommendations. Provide measurements to verify lead length limitations on communication circuit cabling have not been exceeded.
 - l. Electrical cables shall have jackets that will not degrade after prolonged exposure to UV light.
 - m. Panel-mounted computers shall be installed in field and are not to be shipped with panel.
 - n. Refer to Specification Section 40 99 90, Package Control Systems, for requirements for control panel fabrication.
 - o. Construct with structural reinforcements to ensure a plane surface, limit vibration, and to provide rigidity during shipment, installation, and operation without distortion or damage.

- p. Construct panel layout and equipment spacing to allow for device removal, calibration, and maintenance without disassembly of adjacent devices.
- q. Do not perforate external surface of enclosure for purpose of mounting enclosure components (both internal and external) without prior permission of Contracting Officer. Enclosure components requiring such fixation shall utilize fusion welded capacitor discharge type studs.
- r. Isolate electrical components from wetted parts.
- s. Arrange components in enclosure such that failure of a component requires removal of failed component only.
- t. Systems where groups of components are enclosed and serviced as a subsystem will not be permitted.
- u. Install terminal blocks, relays, and other wiring and devices on panel backplate.
- v. Separately mount and identify terminal strips used for power, analog inputs, analog outputs, digital inputs, and digital outputs.
- w. Order of terminal block sections, one for each card, shall match order of cards as they appear in rack. Each terminal block section shall match numbering convention of card.
- x. Provide terminal blocks for used and spare PLC I/O cards.
- y. Digital, analog and power devices such as relays, terminals and wire must be separated and clearly marked.
- z. Control wiring shall be segregated within each panel based on voltage.
- aa. Voltages above 120 volts shall be separated by a solid metal barrier.
- bb. Analog and 24V dc discrete control wiring shall be kept separate from ac wiring.
- cc. Size wire for connected loads and include calculations for verification, showing appropriate derating, where needed.
- dd. Safety Interlock:
 - 1) Prevents panel from being opened when main panel electrical disconnect is closed. Alternatively, interlock may be provided to disconnect power from panel when door is opened.
 - 2) In accordance with panel ratings of UL, local ordinances, and Plant safety rules noted herein.
- ee. Enclosure:
 - 1) House electrical components in NEMA 4X enclosure with suitable side- or top-mounted air conditioning.
 - 2) Provide with flush hinges and automotive-type latch capable of accepting a shackle padlock.
 - 3) Doors shall open through 180 degrees without restriction.
 - 4) Provide three-point latch assembly for 3 foot-high and larger doors.

- 5) Construct to accommodate accessories such as instrument air, power, power supplies, mounting hardware, terminal blocks, and signal conditioning or conversion equipment that may be necessary for monitored and controlled equipment mounted in enclosure.
- 6) Internal Back Panel: Removable type, mounted 2 inches clear from rear of panel.
- 7) Do not install devices on side plates.
- 8) Supply enclosures containing PLCs or OIUs with print pockets, located on inside bottom of enclosure door. Make and color of print pocket shall be same as enclosure interior.
- ff. Power Transformer:
 - 1) Dry type, copper winding, and emit noise at less than 82 dBA.
 - 2) UV Supplier shall include, if necessary, transformer to supply required voltage for PCP within PCP or in separate enclosure of equal construction.
2. Functional Characteristics:
 - a. Each PCP shall be designed to operate with the following electrical supply:
 - 1) 480V/277V, three-phase, four-wire + ground, 60 Hz, 9.4 kVA.
 - b. A Communication Control Board (CCB) and HMI user interface shall be located on the door of the PCP. The CCB monitors the UV chamber and the HMI user interface provides system status, alarms and control for the UV chamber.
 - c. PCPs shall communicate with the Plant PCS/SCADA, where the overall UV system shall be controlled.
 - 1) Plant PCS/SCADA shall control the number of UV reactors on duty and identification of the duty reactor(s).
 - 2) Plant PCS/SCADA shall control the valves to direct flow into the duty reactor(s)
 - 3) Plant PCS/SCADA shall control the initiation/termination of the UV recirculation when there is not sufficient flow to the UV system to maintain minimum flow requirements.
3. Performance Characteristics:
 - a. Provide harmonic mitigation in order that total harmonics, both voltage and current, do not exceed 5 percent, and individual harmonics do not exceed 3 percent, at input terminals of panel. Harmonic testing to be conducted during performance testing as defined in Article Field Quality Control.
 - b. Maximum Temperature:
 - 1) Provide cooling to prevent high temperatures from shortening life of equipment mounted inside.
 - 2) No location within panel or interior of equipment mounted inside shall reach temperatures higher than 45 degrees C.

- c. Minimum Temperature:
 - 1) Electric heating to prevent low temperatures from causing condensation or freezing of equipment mounted inside.
 - 2) No location within panel or interior of equipment mounted inside shall reach temperatures below 10 degrees C.

K. Spare Parts:

- 1. The following spare parts and safety equipment shall be supplied:
 - a. Four UV lamps.
 - b. One sleeve.
 - c. Set of seals and O-rings for one reactor.
 - d. Set of replacement wiper seals for one reactor.
 - e. One face shield, able to block UV light wavelengths between 200 nm and 400 nm.

L. Instrumentation and Control:

- 1. General: In accordance with general control requirement specified in Section 40 99 90, Package Control Systems.
- 2. Physical Characteristics:
 - a. Operator Interface Terminal (OIT):
 - 1) Panel-mounted graphical operator interface capable of bidirectional communication with PLC-based control system.
 - 2) Include cables and ports to interface with PLC control system, personal computers, and external compact flash drives.
 - 3) Graphic Display Screens: Match configuration of plant control system workstations with respect to color usage conventions, general formatting, and screen navigation.
 - 4) Refer to Section 40 99 90, Package Control Systems, for OIT requirements.
- 3. Functional Characteristics:
 - a. Control hardware and software for a given reactor shall be contained within the associated PCP. Each PCP shall monitor one UV reactor and shall pass signals to/from the plant PLC to provide total disinfection system control.
 - b. Each PCP shall interface to plant PCS/SCADA using Ethernet/IP communications. UV reactor shall interface to PCPs using communication protocol and cable as required by vendor. The PCP shall respond to Plant Influent flow signal provided by plant PLC by starting and stopping individual reactors as required.
 - c. Provide instrumentation and control which allows for UV disinfection process to be fully automated and deliver required

- UV dose under conditions of varying flow rates, UV lamp intensity, and varying UV transmittance.
- d. Program functions, I/O addresses, and controller tags within PCPs shall be accessible by SCADA system.
 - e. Coordinate controller tag units, ranges, and conventions to facilitate data exchange.
 - f. Provide hard and native format electronic copies of software installed in UV Supplier's PCP and OITs, annotated to carefully detail program instruction functions and purposes.
 - g. Communications:
 - 1) 10/100 Mbps EtherNet/IP communications ports.
 - 2) Utilize Modbus communications for UV dosimeter communications.
 - 3) Utilize 10/100 Mbps EtherNet/IP communications for OIUs and Plant SCADA.
 - h. Power Supply Module: As required.
 - i. Digital Input Module: Isolated inputs.
 - j. Digital Output Module: Relay outputs.
 - k. Analog Input Module: 4 mA to 20 mA, isolated.
 - l. Analog Output Module: 4 mA to 20 mA, isolated.
 - m. Control System Hierarchy: UV Supplier shall apply through hardware and PLC/OIT software the following standard control hierarchy/modes to SCADA controlled devices:
 - 1) LOCAL:
 - a) When controlled device's physical LOCAL/REMOTE switch is placed in LOCAL, operator has direct control over each device by means of its physical controls, situated at device.
 - b) Mode prevents SCADA manual and automatic control functions.
 - c) SCADA system retains device status monitoring functions under CONTROL mode.
 - d) Switching between LOCAL and REMOTE shall be bumpless, retaining last operational status.
 - 2) REMOTE AUTO (AUTO):
 - a) With device's LOCAL/REMOTE physical switch remaining in REMOTE position and its SCADA based control placed in AUTO, a device or a set of associated devices in a larger process unit, shall be automatically controlled by logic and associated setpoints within PLC(s), generally without user intervention.
 - b) MANUAL controls are disabled.
 - c) Switching between AUTO and MANUAL shall be bumpless.

- d) Operator shall have capability to adjust control setpoints and parameters of equipment set in AUTO control mode.
- 3) Operator shall have capability to OPEN/CLOSE valves or adjust position when applicable.
- 4) Provide safeguards and warnings to prevent accidental change of state.
- 5) Each PCP shall calculate UV RED based on flow rate through UV reactor, user-input UV transmittance, and UV intensity measurements in UV reactor.
- 6) The UV reactor flow rate shall be read by the plant PLC, to which the flowmeters are wired.
- 7) UV transmittance signal shall be read by plant PLC, to which UV transmittance analyzer is wired. Each PCP shall receive the UVT value from the plant PLC.
- 8) UV control system shall maintain required UV dose and send an alarm to plant control system if it is unable to maintain dose setpoints.
- 9) UV control system shall monitor for equipment failure or malfunction and shut down reactor in response to such a failure.
- 10) Plant main SCADA shall provide permission to start a UV reactor. If permission is given, UV reactor shall be allowed to warm up.
- 11) Influent valve of UV reactor shall not be opened until warm-up cycle has finished and SYSTEM READY signal is received from plant SCADA.
- 12) Upon loss of flow signal, UV system shall remain in its current state of operation (maintain valid last operating condition and alarm the event).
- 13) UV Supplier and the System Integrator shall provide synchronization mechanisms and logic within their systems such that UV Control System OIT and SCADA alarm display and acknowledgement maintains synchronization.
- 14) The PCPs shall communicate signals with plant PLC by way of the following protocol:
 - a) Where data from one PLC is needed by another PLC over a network connection, noncached message commands are used to READ data between PLCs. In order to avoid overwriting local control commands in a receiving PLC, use of WRITE messages is not allowed.
 - b) The PCPs shall communicate signals with the plant PLC through the flowmeters on the UV influent pipes and recirculate the UV effluent flow from the UV effluent booster pumps back to the UV reactor during

low or no flow conditions, ensuring continuous operation of the UV reactors and preventing overheating.

- n. Inputs/Outputs:
 - 1) Interface between UV reactor and PCP:
 - a) UV Intensity.
 - b) UV Reactor Temperature.
 - c) Automatic Wiper Position.
- o. External Interfaces:
 - 1) The following signals shall be sent from plant PLC via Ethernet Network as a minimum:
 - a) Influent Valve Open Status.
 - b) UV Reactor Flow Rate.
 - c) UV Reactor Run Enable Permissive.
 - d) UV Transmittance.
 - e) Flow Rate.
 - 2) The following signals shall be sent to plant PLC via Ethernet:
 - a) Reactor Status.
 - b) UV Lamp Status.
 - c) UV Lamp Percent Power.
 - d) Automatic Wiper Status.
 - e) Automatic Wiper Count.
 - f) Ballast Power Level.
 - g) Lamp ON/OFF status.
 - h) Reactor Running Status.
 - i) Common Critical Alarm Out.
 - j) Common Major Alarm Out.
 - k) Common Minor Alarm Out.
 - l) System Ready to Turn On.
 - m) UV Intensity (per lamp).
 - n) Required UV Dose (mJ/cm^2).
 - o) Lamp Run Time (Hours).
 - 3) As a minimum, UV control system shall provide the following minor alarms to plant PLC, but shall not automatically shut down UV reactor:
 - a) Lamp run time hours exceeded.
 - b) UV intensity sensor calibration check required.
 - c) Measured UVT above validated range, revert to maximum validated UVT.
 - d) Loss of UVT signal, revert to minimum design UVT.
 - e) Loss of Flow signal, remain in its current state of operation.
 - f) Measured flow below validated range, revert to minimum validated flow.
 - g) SCADA communication failure.

- 4) As a minimum, UV control system shall provide the following major alarms to plant PLC but shall not shut down UV reactor:
 - a) Measured UVT below validated range.
 - b) Measured flow above validated range.
 - c) Low UV dose.
 - d) UV intensity sensor signal loss.
 - e) Wiper Travel Time Exceeded.
 - f) Wiper Home Limit Fault.
 - 5) As a minimum, UV control system shall provide the following critical alarms to plant PLC and shall automatically shut down duty UV reactor and activate standby UV reactor:
 - a) Lamp failure.
 - b) Ballast failure.
 - c) Cabinet high temperature.
 - d) High reactor/lamp temperature.
 - e) Ballast high temperature.
4. Performance Characteristics: None.

M. Field Instruments:

1. UV Transmittance Analyzer:
 - a. Physical Characteristics:
 - 1) Continuous reading, flow-through UV transmittance spectrophotometer suitable for measurement of UV transmittance of UV influent.
 - 2) Unit shall be self-contained and include sensor and analyzer.
 - 3) Sensor shall consist of UV light source, filter, sample cell, and detector.
 - 4) Pushbutton electronic LCD interface.
 - b. Functional Characteristics: None.
 - c. Performance Characteristics:
 - 1) Analyzer shall comply with accuracy, uncertainty, and reliability requirements defined in the USEPA UVDGM.
 - 2) UVT Range: 0 percent to 100 percent at 254 nm.
 - 3) Acceptable Sample Turbidity: 5.0 NTU.
 - 4) Lamp Life: 9,000 hours minimum.
 - 5) Measurement Frequency: One every 2 minutes.
 - 6) Self Diagnostics, Via Local Display:
 - a) Lamp failure.
 - b) UV sensor dark reading out of range.
 - c) System cleaning required.
 - d) Drive system failure.
 - e) Home position not found.

- f) Low flow.
- g) Measured UVT out of range.
- 7) Electrical:
 - a) Power Requirements: 10 amps, 100V ac to 240V ac, 50 Hz to 60 Hz.
 - b) Enclosure: Wall mounted, NEMA Type 4X/IP66.
 - c) Signal Outputs:
 - (1) Two 4 mA to 20 mA proportional to 65 percent to 100 percent UVT.
 - (2) One Form C Common Alarm Contact, Rated for 5 amps at 240V ac.
 - d) Electrical Connection (Power): 19 mm NPT.
 - e) Electrical Connection (Controls): 19 mm NPT.
 - f) UL Approved.
- 8) Environmental:
 - a) Indoor, nonfreezing service.
 - b) Operating Temperature:
 - (1) Sample: 2 degrees C to 40 degrees C.
 - (2) Ambient: 2 degrees C to 40 degrees C.
 - c) Humidity: 0 percent to 100 percent condensing.

2.04 SAFETY FEATURES

- A. Provide two goggles or glasses that blocks UV light wavelengths between 200 nm and 400 nm.
- B. Each UV reactor shall be equipped with a temperature switch to prevent the reactor from overheating. The temperature switch shall be wired to the PCP and, when activated, will shut the reactor down and initiate a critical alarm condition.
- C. Each UV reactor service entrance will be covered with a removable end cap to protect the lamps and electrical connections. For operator safety, the protective cover will be equipped with a switch to disconnect power to the lamps when the cover is removed.

2.05 ACCESSORIES

- A. Physical Characteristics:
 - 1. Equipment Identification Plates: Provide 16-gauge Type 316 stainless steel identification plate securely mounted on each separate equipment component and control panel in a readily visible location. Plate shall bear 3/8-inch high die-stamped block type black enamel filled equipment identification number and letters indicated in this specification and as shown.

2. Lifting Lugs: Provide suitably attached for equipment assemblies and components weighing over 100 pounds.
3. Anchor Bolts: Type 316 stainless steel, sized by equipment manufacturer.

B. Functional Characteristics: None.

C. Performance Characteristics: None.

2.06 SOURCE QUALITY CONTROL

A. General:

1. Do not ship UV System until factory test report is approved by Contracting Officer.
2. Factory test major components of UV System for compliance with specified requirements during a single test session.
3. Factory test shall demonstrate that each individual UV System operates as specified.
4. Arrange for one or more factory tests to confirm demonstration of communication with plant PLC and acceptance of OIT by Contracting Officer.
5. Contracting Officer may elect to witness tests. Costs to witness shall be responsibility of the Government.
6. Components shall be fully assembled and hydrotested at 1.5 times design pressure at factory prior to shipment.

B. Factory Test Plan and Report:

1. Develop and submit test plan. Plan shall include, but not limited to:
 - a. Daily test schedule for duration of test.
 - b. Delivery of UV dosage.
 - c. Lamps.
 - d. Intensity sensors.
 - e. Cleaning system.
 - f. Control power panel for each reactor.
 - g. Instrumentation and controls for each reactor.
 - h. Operator interface units.
2. Upon conclusion of test, submit test report documenting tests performed, items witnessed, and results.

C. Factory Test:

1. Assemble PLC control panels, remote I/O control panels, and OIT computers to demonstrate control system.
2. Provide communications links between respective panels and computers to simulate complete system.

3. Verify functions of UV control system via simulation or other methods.
4. Demonstrate each component operates as specified.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Install UV system in accordance with the Drawings, manufacturer's engineering drawings and instructions.
- B. Contractor shall provide and install anchor bolts, fasteners, washers, and templates needed for installation of UV Equipment.
- C. Provide 2-inch gap between rear of panel and wall for new, freestanding, and wall mounted enclosures.
- D. UV Supplier shall supervise work of Contractor including but not limited to installation of the following UV system components:
 1. UV reactor, PCPs, and interconnecting control/power wiring.
 2. UV system OIT.
 3. Verify field wiring I/O connections made by Contractor to respective PCP.
 4. Inspect, test, and verify communications links from respective PCP to plant SCADA.

3.02 FIELD FINISHING

- A. Control and Power Panels: As specified in Section 09 90 00, Painting and Coating.

3.03 FIELD QUALITY CONTROL

- A. General:
 1. UV Supplier shall complete Manufacturer's Certificate of Proper Installation upon satisfactory installation of UV System.
 2. In accordance with Section 01 91 14, Equipment Testing and Facility Startup.
 3. UV Supplier shall calibrate instruments, sensors, and meters supplied for testing, including UVT analyzers, UV intensity sensors, and power consumption meters.
- B. Definitions of UV Reactor/Component Failure:
 1. UV lamps shall be deemed to have failed when:
 - a. Lamp fails to light when powered.

- b. Lamp fails to achieve performance requirements for disinfection specified herein.
 - c. UV intensity falls below UV Supplier's guaranteed end of life output, with UVT greater than or equal to design value.
- 2. UV sleeves shall be deemed to have failed when:
 - a. Sleeve breaks or leaks water while operating within conditions specified herein.
 - b. Sleeve output falls below UV Supplier's guaranteed end of life output immediately after sleeve cleaning.
- 3. UV ballasts shall be deemed to have failed when ballasts fail to properly operate UV lamps.
- 4. UV intensity sensors shall be deemed to have failed when:
 - a. Sensors, duty or reference, are not able to be calibrated at factory.
 - b. Sensors drift out of calibration more than twice per year when checked monthly with reference intensity sensor per USEPA UVDGM guidelines.
- 5. UVT analyzer shall be deemed to have failed when:
 - a. Analyzer fails to operate properly.
 - b. Analyzer drifts out of calibration more than once per month when checked weekly against a bench-top spectrophotometer per USEPA UVDGM guidelines.
- 6. UV reactor shall be deemed to have failed when minimum required RED, as specified herein, cannot be achieved under conditions that include flow, UVT, and lamp and sleeve life within design values.

C. Functional Tests:

- 1. With assistance from UV Supplier conduct to satisfaction of Contracting Officer prior to commencing Facility Startup.
- 2. Purpose shall be to demonstrate effectiveness of UV system components and control features in all modes of control.
- 3. Conduct dry testing first, with a follow-up period of wet testing. UV Supplier shall identify tests that shall be completed with a dry reactor and those that require wet testing.
- 4. Testing shall include:
 - a. Automatic START/STOP of UV reactor by SCADA OIT(s) and control system(s).
 - b. Manual START/STOP of UV reactor by SCADA OIT(s) and control system(s).
 - c. Automatic shutoff and alarms for various failure modes for UV reactor, including but not limited to loss of UVT or flow rate signals, lamp or ballast failure, low water level in reactor, high temperature, and cleaning system failure.
 - d. Monitoring and trending of operating data.
 - e. Monitoring and control from remote workstation.

- f. Automatic switchover from normal power to emergency power, and emergency power to normal power.
 - g. UV reactor cleaning system operation.
 - h. Monitoring instruments operation.
 - i. Control functions, both at local system and remote workstation.
 - j. Modifying lamp output to verify UV intensity sensors can detect changes in UV intensity.
- 5. In the case of a nonconforming system not caused by external equipment or processes, as determined by the Contracting Officer, advancement to performance testing shall not commence until the UV system manufacturer has made, at no additional cost to the Government or Installing Contractor, such adjustments and modifications as are necessary to correct the system, and has demonstrated this by repeating the functional testing until satisfactory.
 - 6. Functional Testing is not complete until Function Test report is submitted and accepted by Contracting Officer.

D. Performance Testing:

- 1. Performance testing and startup shall not commence until the Certificate of Proper Installation and functional testing report has been submitted and accepted.
- 2. Successful performance testing shall be defined as 14 calendar days of continuous operation without production of off-specification water as a result of failure of a UV System component and demonstration that UV system meets performance requirements established herein. Downtime resulting from plant's operation, including flow or UVT outside of UV reactor's validated range, will not be counted against criteria of "continuous days of operation."
- 3. Performance Testing shall include:
 - a. An extended period of UV operation including normal starts, stops, and changeover to backup UV reactor.
 - b. For each installed reactor verification of normal and emergency operation without malfunction, for example reactor failure or loss of UVT signal.
 - c. Headloss check, power consumption check, UVT and intensity sensor calibration checks, power factor measurements, and UV System dose check based on UV System control panel readings and calculations. Specifically include:
 - 1) Two UVT analyzer calibration and reading stability check with use of Government's laboratory spectrophotometer, and prepare documentation on compliance with USEPA UVDGM requirements.
 - 2) Sensor calibration check of supplied/installed duty and reference sensors. Provide calibration ratio for each individual sensor calibration check. Prepare documentation

on duty UV sensors' compliance with USEPA UVDGM requirements.

- 3) Measure 'S_o' at the beginning of Performance Test. Measure 'S' for each lamp in each reactor at end of Performance Test. Calculate S/S_o for each lamp/sensor. Identify results that are outside of manufacturer expectations.
- d. Microbial Inactivation: The purpose of the microbial inactivation sampling is to confirm that the effluent quality meets the design requirements under actual operating conditions.
 - 1) The test medium shall be unchlorinated permeate within the following range:
 - a) Minimum UVT is 65 percent.
 - b) Maximum Turbidity is 5 NTU.
 - c) Maximum Iron is 0.1 mg/L.
 - d) Flow Range shall be between 0.1 mgd to 1.2 mgd.
 - 2) The UV supplier shall collect and analyze at least three concurrent pairs of influent and effluent samples to demonstrate compliance with the requirements of this section. During this performance test period, the UV supplier shall provide all labor, sampling containers, and analytical services required. Contracting Officer will provide flow and power to operate the system.
 - 3) At the same time samples are collected, date/time, flow, lamp intensity, lamp age, lamp power settings, lamps in service, number of reactors in operation, water temperature, headloss and UV dose shall be recorded.
 - 4) The UV supplier shall perform the following schedule of tests, with all elements sampled concurrently:

Test	Sample Location	Frequency	Procedure
Total Coliforms	System inlet and outlet	1 time/day each weekday	Standard Methods (Method 9221)
UVT	System inlet	2 times/day	Standard Methods (Method 5910)
TSS	System inlet	1 time/day	Standard Methods (Method 2540D)

- 5) Each microbial inactivation sample will be considered to be successful (pass) if the effluent total coliform level is less than 2.2 MPN/100 mL 7-day median maximum for a geometric mean and all single grab samples are less than 23 MPN/100 mL. In all cases, the UV dose setpoint shall be the design dose.
- 6) All costs associated with the re-design of the UV system to accommodate any necessary changes incurred for not

- meeting system performance requirements shall be the sole responsibility of the UV system manufacturer including any additional facilities' capital and O&M costs.
4. Test Report: UV Supplier shall be responsible for coordination and inclusion in report of data and results required to meet reporting requirements whether raw data is contained in UV Supplier's PLC or plant PLCs or SCADA. As a minimum, results shall be provided as follows:
 - a. Daily tabulated data, provide range and average if applicable, of recorded information.
 - b. Energy:
 - 1) Average and range of energy consumption per day, data provided by the Contracting Officer.
 - 2) Average energy consumption per volume of net water treated.
 - 3) Total and individual current harmonic distortion, up to and including 35th harmonic.
 - 4) Power factor of PDC.
 - c. Headloss across reactor at minimum, average, and maximum flow if available.
 - d. Other:
 - 1) Quantity of sleeve cleaning cycles and recommended automatic cleaning wiper cycle frequency for operations.
 - 2) List of parts replaced and reasons for replacement.
 - 3) List and results of calibration or other maintenance activities performed and reasons.
 - 4) Summary of off-specification occurrences.
 - e. Results from offsite lamp output, sleeve transmittance, and UV intensity sensor verifications, if applicable.
 5. Performance Testing is not complete until this report is submitted and approved by Contracting Officer.

3.04 MANUFACTURER'S SERVICES

- A. Field services shall conform to Section 01 43 33, Manufacturers' Field Services, and Section 01 91 14, Equipment Testing and Facility Startup.
- B. Manufacturer's Representative:
 1. Present at Site or classroom designated by Contracting Officer, for minimum person-days listed below, travel time excluded:
 - a. 2 person-days to attend process and instrumentation/control design coordination workshops.
 - b. 3 person-days total in one trip of onsite supervision of Contractor installation of UV system and completion of Manufacturer's Certificate of Proper Installation.

- c. 4 person-days in one trip for Functional Testing.
- d. 3 person-days for one trip for Bioassay Spot Check Commissioning Testing.
- e. 8 person-days in two trip for Performance Testing.
- f. 6 person-days in two trip for facility startup and commissioning assistance.
- g. 2 person-days in one trip for post-startup training of Government's personnel.

3.05 TRAINING

A. General:

- 1. Training shall not commence until accepted detailed lesson plan for each training activity has been reviewed by Government.
- 2. Provide for training of designated Government's personnel in operation and maintenance of UV system.
- 3. Training shall consist of both classroom and hands-on sessions conducted at time and location acceptable to Government.
- 4. Designate a person responsible for scheduling and coordinating training.
- 5. Training sessions may be recorded if Government so chooses. If sessions are to be recorded, provide necessary recording equipment.

B. Manufacturer's personnel shall provide detailed system training including, as a minimum, the following:

- 1. System operations philosophy.
- 2. System Control:
 - a. Loop Functions: Understanding loop functions, including interlocks.
 - b. Loop Operation: For example, adjusting process variable setpoints, and control, and annunciator acknowledgment and resetting.
 - c. Interfaces with other loops and subsystems.
- 3. Operator interface/system setpoints.
- 4. Component performance requirements.
- 5. Component functions.
- 6. Component maintenance.
- 7. Component troubleshooting.
- 8. Instrument operation, maintenance, troubleshooting, replacement, and calibration procedures.

C. Coordinate training periods with Government's operating personnel and manufacturer's representatives, and with submittal of O&M Manuals.

- 1. Initial training shall be completed at least 10 days prior to startup, but not more than 30 days prior to startup.

2. Operation and Maintenance Manuals shall be reviewed, accepted, and resubmitted in accordance with this section before start of training. Modifications resulting from startup of facility shall be incorporated into final manuals.
 3. The Contracting Officer reserves the right to video tape training for future training of new operators. The videos will remain the property of the Government and will not be distributed to any third party. All training services shall be presented twice (two identical sessions) at times coordinated with the Government to allow all Government's personnel to attend.
- D. See Section 01 43 33, Manufacturers' Field Services, and Section 01 91 14, Equipment Testing and Facility Startup.

END OF SECTION

