DATE: May 1, 2001, **Revised June 10, 2013**

TO: Office of Drinking Water Staff

FROM: John J. Aulbach II, PE, Director
Office of Drinking Water

SUBJECT: DESIGN & CONSTRUCTION - TREATMENT - UV Disinfection Systems for Public Water Supplies

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SUMMARY STATEMENT:

Disinfection by ultraviolet (UV) light is an option for waterworks to meet the disinfection requirements as described in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). This memo addresses the process design features and controls, approval procedures, waterworks classification, and monitoring and reporting requirements for waterworks that employ UV treatment. The requirements presented in this memo are intended for facilities desiring to obtain UV log-inactivation credit for *Giardia lamblia*, and *Cryptosporidium.*

This memo also addresses the use of UV equipment in groundwater systems that are not required by the Regulations or the Virginia Department of Health (VDH) to disinfect, in a separate Appendix B.

Revision Highlights: Complete rewrite of previous memo to incorporate final Long Term 2 Enhanced Surface Water Treatment Rule (LT2) and Groundwater Rule (GWR), and EPA's *UV Disinfection Guidance Manual*. Provides design requirements, review and approval procedures for UV installations, and monitoring and reporting requirements. Provides forms for consultants, operators and VDH staff.

TABLE OF CONTENTS

APPENDICES

ATTACHMENTS

ENGINEERING HANDOUTS / REVIEW FORMS:

A. ULTRAVIOLET (UV) DISINFECTION PROJECT REVIEW FORM

B. CONTENT OF UV EQUIPMENT SPECIFICATIONS

C. UV REACTOR DOCUMENTATION FOR VALIDATION TEST

D. UV VALIDATION TEST PLAN CONTENTS

E. UV VALIDATION TEST REPORT REVIEW

F. ON-SITE VALIDATION TESTING REVIEW OF QUALITY ASSURANCE/QUALITY CONTROL

MONTHLY OPERATION REPORTS (EXCEL SPREADSHEETS):

G. MONTHLY OPERATION REPORT FORMS

- UV Reactor Operation Summary
- UV Operation Log - Calculated Dose Control
- UV Operation Log - UV Intensity Setpoint Control
- UV Operation: Off-Spec Calculation Worksheet
- UV Sensor Calibration Report
- UV Sensor Correction Factor (CF) Worksheet
- UVT Analyzer Calibration Check Log

SPECIAL PERMIT REQUIRMENTS:

H. SPECIAL UV PERMIT REQUIREMENTS DURING PROVISIONAL OPERATING PERIOD (Including UV Performance Testing)

I. SPECIAL UV PERMIT REQUIREMENTS - STANDARD OPERATION PERMIT

I. BACKGROUND

A. General

UV may offer a cost-effective approach to meeting both disinfection performance and disinfection by-product regulatory requirements, and is likely to receive increasing consideration among water system owners, operators and water treatment design engineers. The *Waterworks Regulations* identifies UV as one option in the "microbial toolbox" that may be used by surface water or groundwater under the direct influence of surface water (GUDI) systems to obtain disinfection credit. UV systems using low pressure lamps (monochromatic light output at 254 nm) will be considered for disinfection credit, in accordance with the *Waterworks Regulations (12VAC5-590-420.B.3.d.(7)(c)),* which specifies UV dose requirements for inactivation of *Giardia lamblia*, viruses, and *Cryptosporidium*. Medium pressure lamps (polychromatic light output at multiple wavelengths) will be evaluated and approved on a case-by-case basis.

Systems must use UV reactors that have undergone validation testing to determine the operating conditions under which the required UV dose is delivered.[1] UV reactor monitoring, reporting and record-keeping requirements are specified in the *Waterworks Regulations*.

Additionally, the Groundwater Rule may impose treatment technique requirements on a ground water system with fecal coliform contamination of source water or with Significant Deficiencies. The treatment techniques must reliably achieve at least 4-log treatment of viruses using inactivation, removal, or a combination of the two, before or at the first customer. However, the Groundwater Rule Implementation Guidance cautions against using UV as a stand-alone technology to achieve 4-log virus inactivation. This is because adenoviruses, and other viruses, are more resistant to UV inactivation. Therefore, UV will not be approved at this time as an "alternative treatment" to meet the requirements of the Groundwater Rule.

B. Reference Publications

The Virginia Department of Health policy and procedures regarding UV disinfection in public drinking water systems are based on the following:

- LT2ESWTR, finalized on December 15, 2005
- Ultraviolet Disinfection Guidance Manual for Final Long Term 2 Enhanced Surface Water Treatment Rule, EPA 815-R-06-007, November 2006 (hereinafter referred to as the ***UV Disinfection Guidance Manual)***
- Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse, by the National Water Research Institute and the Water Research Foundation, 3rd edition, 2012 (hereinafter referred to as ***NWRI / WaterRF Guidelines)***
- Groundwater Rule, finalized on November 8, 2006
- Groundwater Rule Implementation Guidance, EPA 816-R-09-004, January 2009

[1] The UV dose table in the *Waterworks Regulations* is applicable only to post-filter installations. The dose tables are based on using low-pressure mercury lamps producing UV at a wavelength of 254 nm. To receive treatment credit for other lamp types, systems must demonstrate an equivalent germicidal dose through reactor validation testing.

- NSF/ANSI Standard 55-2012: Ultraviolet Microbiological Water Treatment Systems
- Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems, EPA 815-R-06-010, April 2006
- Design and Performance Guidelines for UV Sensor Systems, Water Research Foundation, Project #91236, September 2009
- Optimization of UV Disinfection, Water Research Foundation, Project #2983, © 2007

II. APPROVAL PROCEDURES FOR SURFACE WATER AND GUDI SYSTEMS REQUESTING DISINFECTION CREDIT

A. Overview

UV will not be approved as the only disinfectant, or as a substitute for filtration requirements at surface water and GUDI sources. Additional disinfection credit will only be considered for UV treatment in accordance with the *Waterworks Regulations.*

The following procedures are to be followed:

1. The Preliminary Engineering Conference (PEC) and Report (PER) are required.
2. UV Equipment Validation Testing is required. A **Validation Test Plan** is required for approval before on-site testing is initiated. A **Validation Report** must be submitted and approved by VDH before or with the final plans and specifications. This report must contain documentation for the UV reactor, the Validation Test Plan, and the test results. {Note that pre-purchase or pre-selection of the UV equipment will most likely occur *before* the final facility design is completed.}
3. Final Design Plans and Specifications are required for VDH review and issuance of a Construction Permit.
4. Testing, Start-Up & On-Site Inspections must be coordinated with the owner, consultant and contractor. Inspections may be required prior to Validation Testing (if validation testing is performed on-site), and after functional testing is completed.
5. A Provisional Operation Permit will be issued for a minimum period of 12 months. A report of all the performance testing and monitoring during the provisional operation period will be required for review and approval by VDH prior to issuance of a standard Operation Permit.

A flowchart describing the approval process for systems requesting disinfection credit is given in APPENDIX A. Groundwater systems that will not receive disinfection credit for UV reactor installations are to be considered using the procedures given in APPENDIX B.

B. Preliminary Engineering Conference and Report

A project applicant must submit a Preliminary Engineering Report (PER) to VDH and obtain approval *prior to* submission of equipment specifications or final design plans. The suggested topics of the PEC and the contents of a PER are provided in APPENDIX C.

To simplify the review and approval of the UV facility plans and specifications, the District Engineer should provide the following attachments, which are published in the *EPA Guidance*

Manual:

1. A table listing the required content of the UV specifications to the owner/consultant at the PEC. The table is included in ATTACHMENT B. (Deviations may be accepted by VDH, on a case-by-case basis.)

2. UV reactor validation testing forms in ATTACHMENTS C through F.

3. Example Monthly Operation Reports and UV calibration worksheets, as Excel spreadsheets, in ATTACHMENT G.

C. Reactor Validation Testing

UV equipment must be validated if credit for inactivation of *Cryptosporidium* or *Giardia lamblia* is desired. The purpose of the validation testing is to determine the operating conditions under which a UV reactor delivers the required "validated dose" (millijoule/cm^2) needed to achieve log inactivation credit. {UV sensors measure the intensity of UV light (in milliwatts/cm^2), but they cannot measure the dose delivered to the microbes.} Validation testing of UV equipment may be performed on-site at the waterworks or off-site. Off-site validation is preferred.

Validation testing, whether on-site or off-site, must be performed by a third party (independent of the UV reactor manufacturer) to ensure that validation testing and data analyses are conducted in a technically sound manner and without bias. Individuals qualified for such oversight include engineers experienced in testing and evaluating UV reactors and scientists experienced in the microbial aspects of biodosimetry. Appropriate individuals must have no real or apparent conflicts of interest regarding the ultimate use of the UV reactor being tested.

The validated operating conditions must include flow rate, UV intensity as measured by a UV sensor, and UV lamp status. Validation testing must include:

- Full-scale testing of a reactor that conforms uniformly to the UV reactors proposed for use by the water system, and
- Inactivation of test microorganism whose dose-response characteristics have been quantified with a low-pressure mercury vapor lamp.

Validation testing must account for:

- UV absorbance of the water;
- Lamp fouling and aging;
- Measurement uncertainty of on-line sensors;
- UV dose distributions arising from the velocity profiles through the reactor;
- Failure of UV lamps or other critical components; and
- Inlet and outlet piping or channel configurations of the UV reactor.

The standard validation testing uses the biodosimetry validation protocol as recommended and described in the *UV Disinfection Guidance Manual*. Specific information for implementing the biodosimetry validation protocol and evaluating the results are described in Section 5.2 through 5.10 of the Manual. Alternate microorganisms listed in the *UV Disinfection Guidance Manual* for the validation of reactors for *Cryptosporidium* and *Giardia* credit may be considered.

UV reactors certified by ÖNORM and DVGW for a *Bacillus subtilis* Reduction Equivalent Dose (RED) of 40 mJ/cm^2 may be granted 3-log *Cryptosporidium* and 3-log *Giardia* inactivation credit.

All other validation protocols, including validation by ***NWRI / WaterRF Guidelines*** and ***NSF-55, Class A criteria,*** will be considered on a case-by-case basis. (Note: At this time, both NWRI and NSF-55 Class A protocols are solely based on using the MS2 microorganism.)

Alternative methods to biodosimetry validation, such as model-based approaches using Computational Fluid Dynamics (CFD), are still under research and will not be approved at this time.

The steps involved in the biodosimetry validation protocol are:

Step 1 - Conduct experimental tests using a challenge microorganism (Bench-scale testing using a collimated beam apparatus, followed by Full-scale reactor testing);

Step 2 - Estimate the Reduction Equivalent Dose; and

Step 3 – Adjust for uncertainty to calculate the validated dose.

A Validation Report must be submitted documenting that the validation requirements have been met, for both on-site and off-site tests. VDH must evaluate the Validation Report for the specific equipment proposed. The purpose of this evaluation is to verify:

- Testing meets the minimum regulatory requirements as summarized in the UV Dose Tables for *Cryptosporidium* and *Giardia lamblia* .
- EPA's recommended validation protocol was followed and any deviations from the protocol are adequately justified.
- Validated doses achieved by the UV equipment meet or exceed the target pathogen log inactivation desired.
- Quality Assurance/Quality Control criteria were met during validation testing.

Off-site validation test reports *may* be included with the PER. Otherwise, test reports must be submitted with the final design plans and specifications.

Note:

1. If ***NWRI / WaterRF Guidelines*** are used, the engineer must be instructed to prepare the report such that it follows the review templates.
2. A report is NOT required for equipment certified by NSF-55 Class A. However, to facilitate review, detailed information in Section 8 of that Standard must be provided.

A certificate provided by the manufacturer is required with the final plans verifying that the equipment design (including: lamp spacing, type of lamp, quartz sleeve characteristics, ballast, and sensors) is identical to the technology used in the validation testing. The conditions at the point of installation and the variability of water quality and flows shall not exceed those used in the validation testing.

D. Plans and Specifications

A project applicant must submit Plans and Specifications to VDH. A summary of the instrumentation and control design should be included in the specifications, for ease of review. A Construction Permit is issued by VDH with approval of the plans and specifications, in accordance with the procedures in the *Regulations*.

E. Start-Up

A start-up plan shall be developed collaboratively by the design engineer, plant operations staff, and the UV manufacturer. The plan must include functional testing, determination of validated operating conditions and control settings, performance testing, development of an Operation and Maintenance (O&M) Manual, and interim/final inspections. VDH must be involved in coordination of the start-up; particularly in defining the extent of testing, scheduling of inspections, and determining whether the water will be sent to the distribution system during this period. The Special Permit Requirements of the Provisional Operating Permit will need to be developed by VDH during the start-up planning.

Functional Testing
Functional testing verifies that the UV equipment was installed in accordance with the plans and specifications. It should include verification of UV equipment components (UV sensors, on-line UVT analyzer (if furnished), lamps, ballasts, cooling system, and cleaning system), calibration and verification of instrumentation and control systems, and flow distribution and headloss. The engineer's Statement of Completion should certify that these items have been checked and are acceptable.

Determine Validated Operational Conditions and Set Operational Controls
Generally the functional testing must be satisfactorily completed before validated operating conditions are established. The operating settings for each level of inactivation credit must be defined for each UV reactor, based on the validation testing results. Operational alarms must also be established to insure operation within validated conditions. These procedures are described in detail in Sections 5, 6 and Appendix B of the *UV Disinfection Guidance Manual.* The engineer's Statement of Completion should certify that these items have been established. These parameters shall be included in the Special Permit Requirements in the Provisional and standard Operation Permit.

Final Inspection
An inspection is required by ODW after receipt of the engineer's Statement of Completion, and then a Provisional Operation Permit is issued.

Performance Testing
At the beginning of the provisional operating period, the equipment must undergo a 100 hour burn-in period, followed by a minimum 4 weeks of performance testing in order to confirm operation within validated settings (see part 6.1.5 and Table 6.2, *UV Disinfection Guidance Manual*, for recommended parameters). The water system may also choose to use this testing period to optimize reactor performance / energy usage.

O&M Manual
The O&M Manual must be site-specific, and developed before the Provisional Operation Permit period is over. Specific topics are suggested in Chapter 6 of the *UV Disinfection Guidance*

Manual. The O&M Manual should include Monthly Operation Report forms to be submitted to VDH, and calibration forms to be used by the operations staff. Suggested Monthly Operation Report forms and calibration check logs have been created in Excel and are included in ATTACHMENT G.

III. SPECIFIC DESIGN REQUIREMENTS FOR SURFACE WATER AND GUDI TREATMENT INSTALLATIONS REQUESTING DISINFECTION CREDIT

A. General

All equipment in contact with product water must be NSF Standard 61 approved. A minimum of two reactors are required, in order to treat the design flow with the largest unit out of service. The following sections outline key design requirements. Further details are included in the EPA's *UV Disinfection Guidance Manual*.

B. Pretreatment

Water quality can affect the amount of lamp sleeve fouling that occurs in UV reactors. Appendix C, Section 3 includes water quality parameter values recommended by Ten State Standards. Manufacturer specific water quality specifications should also be determined. Pretreatment may be required to meet these water quality specifications. Water quality parameter samples should be collected from locations that are representative of potential UV facility location(s).

C. Flow Distribution and Control

It is critical to mimic the hydraulic flow profiles through the reactors to that of the validation conditions. Inlet and outlet piping configuration must be identical to the configuration tested during the validation process, as detailed in the validation report. If an on-site validation is to be performed, the hydraulic configuration must follow manufacturer's recommendations.

A means of flow distribution and control is required when two or more reactor trains are proposed. This may be accomplished in either of two ways, depending on the complexity of the proposed system: 1) active flow control – place individual meter and flow control valve at each reactor train, or 2) passive flow control – monitor flow at each reactor train.

Each reactor train should be supplied with an individual flow meter. However, a single flow meter in conjunction with differential pressure readings at each train may be considered. Magnetic and Doppler flow meters are recommended, to minimize effects on the velocity profile.

D. Lamp Submergence and Entrained Air

Reactors must be installed at an elevation below the hydraulic grade line to ensure that the lamps remain submerged to prevent overheating. Open channels will not be allowed. Flow control valves are a common method to ensure full pipe flow conditions through the reactor.

Air release and vacuum relief valves, or combination air valves, must be installed in the system to prevent air from entering the reactors and to prevent negative gauge pressure conditions. (Air in the reactor can allow the lamps to overheat, while negative pressures can cause the quartz sleeve

to break.)

UVT analyzers must be located to avoid air bubbles in order to perform properly.

E. Isolation Valves

Isolation valves must be installed upstream and downstream of each reactor to allow an individual reactor to be isolated and removed from service for maintenance. Inlet and outlet valve configurations must be coordinated with the validation configuration and manufacturer's recommendations. While not recommended, if the isolation valves are also used for flow control, the downstream valve should be the valve used for flow control. Valve seats, seals, and fittings within straight pipe lengths adjacent to the UV reactors must be UV and chemical (reactor cleaner) resistant to prevent damage.

F. Intermediate Pumping

Installation of intermediate booster pumps may be needed to overcome headloss through a reactor. Since the typical headloss through a reactor is 1 to 8 feet, mixed- or axial-flow pumps, with high flow and low head conditions are generally appropriate. Pumps may be installed before or after reactors, but if located downstream of reactor must have a wetwell between the reactor and pump station. Existing clearwells, recombination channels or a new dedicated pump wetwell may be used. The pumps should be controlled by the water level in the wetwell with consideration given to the lamp warm-up time. Variable frequency drives (VFDs) or rate-of-flow controllers are recommended to minimize flow surges.

G. Pressure Surges

The potential for water hammer needs to be addressed, in particular, surges due to loss of power or downstream valve closure. The system pressure cannot exceed the maximum design pressure of the UV lamps. A surge analysis is recommended, and should include at a minimum: 1) pump start-up and shut-down procedures, and 2) coordination of isolation valves.

H. Sample Taps and Drains

1. Sample taps must be installed in pipes upstream and downstream of each reactor
2. Drain valves or plugs must be provided:
    a) at low points in the UV facility to allow for fully draining reactors and lateral lines during maintenance
    b) between each set of isolation valves
    c) on analyzer lines, with valves installed on the sample line to isolate analyzer

I. Instrumentation and Control

The engineer must provide a summary of the instrumentation proposed, process control of the UV system, and the incorporation of the UV system into the entire treatment plant control system in the final design documents. Elements that are pre-programmed in the UV reactor control panel, necessary supplemental controls to coordinate the reactor trains, actions necessary for each alarm condition, start-up/sequencing procedures, and lamp warm-up considerations must be included.

It is the owner's option as to the degree of automation; from completely manual to fully automatic start-up and operation. If the waterworks will not have full time staff present during UV reactor operation, then remote monitoring and display is required, typically through a SCADA system. Provisions may be granted for use of an auto-dialer to a 24-hour available phone contact.

All UV reactors shall have automatic shutdown under critical alarm conditions, including: lamp/ballast failure, low liquid level, and high temperature. Alarms are also required for: low UV validated dose, low UV intensity, low UV transmittance, high flow rate, and mechanical wiper failure, if applicable. Refer to Table 4.2 of the *UV Disinfection Guidance Manual* for further information.

The following parameters shall be monitored for all UV systems, and displayed locally at each reactor and on SCADA, if available:

- on/off status of each reactor;
- flow rate through each reactor train;
- lamp intensity as measured by UV sensor(s), lamp power, lamp status, lamp age;
- UV intensity of each reactor;
- UV Transmittance (UVT) of each reactor. An online UVT analyzer is only required for systems using the calculated dose approach. A bench top spectrophotometer may be utilized with the transmittance value manually entered into SCADA or the individual reactor control panels. UVT must be displayed on the SCADA system, and it is recommended that it also be displayed locally at each reactor.
- calculated UV dose,
- validated UV dose using empirical dose monitoring equations developed during validation, if calculated dose control is employed;
- operational set points for automated control parameters;

J. Electrical Power Considerations and Back-up Power

Based upon the results of the power quality analysis presented in the PER, upgrades to the power supply system may be required.

Back-up power is recommended for all UV treatment facilities. Facility conditions, historical power outage data, storage availability, water demand, or other factors may be used to justify that the system can reliably supply drinking water during a typical power outage without provision of a standby generator.

Ground Fault Interrupt (GFI) circuits are required for all lamps, and must be included in the specifications. Provisions for both hydraulic and electrical lockout/tagout procedures during maintenance must be included in the O&M Manual. All electrical design and installation must comply with the National Electrical Code, and all applicable local and state electrical requirements.

K. Housing Requirements

A building to enclose and protect all UV equipment is required. Adequate space between control panels, power supply, and the reactor equipment shall be provided to allow for routine operation and maintenance, including removing lamp and wiper assemblies and for off-line chemical cleaning of reactor lamps, if applicable.

L. Safety Equipment

Eye protection against UV light must be provided. If off-line chemical cleaning systems are used, then appropriate personnel protective equipment must also be provided.

M. Spare Parts

Suggested quantities of spare parts on hand: 10% of lamps, 5% of sleeves, ballasts, seals and wipers (if provided).

IV. MONITORING & REPORTING

Continuous monitoring is required for the following parameters at each reactor:

1. UV Intensity as measured by UV sensor(s);
2. UV Transmittance (UVT), if using the calculated dose approach;
3. Validated Dose using empirical dose monitoring equations developed during validation, if using calculated dose control;
4. Lamp Status;
5. Flow Rate through the UV reactor(s).

These parameters must be recorded at a minimum frequency of every 4 hours. Very small systems (serving < 500 persons) may reduce recording frequency to once per day, if manual recording is practiced.

The LT2ESWTR requires that 95% of water produced per month must be within validated operating limits to meet *Cryptosporidium* treatment requirements. Waterworks using UV as a required treatment option to achieve compliance with LT2 cannot be operated by bypassing lamp operations, and must contact VDH immediately if operating off-specification. Off-specification includes operating the UV reactor when calibration of UV sensors has not been verified, operating outside of validated limits, operating a UV sensor and/or a UVT analyzer that is not in calibration and operating with UV equipment that is not better or equivalent to the equipment validated. Off-specification events must be recorded every 5 minutes. The volume of water produced during these events, and total monthly volume, must be recorded and reported monthly to VDH in the Monthly Operation Report. Daily minimum validated dose or intensity, as applicable, is also to be reported. Monthly Operation Report forms, provided in ATTACHMENT G, should be used to report this data.
All UV sensors shall be verified with a reference UV sensor at least monthly.[2] The waterworks

[2] Section 6.4.1.1 of the UV Disinfection Guidance Manual provides recommended sensor calibration evaluation procedures.

should own at least 2 reference UV sensors and possibly more if wet duty sensors are employed.

It is also recommended that off-line/standby sensors be calibrated at the same time. This will allow for rapid change out if the need arises. The reference UV sensor should be calibrated at least yearly. Calibration of reference sensors and testing of new duty sensors should be performed by an accredited laboratory (NIST-NVLAP, or equivalent)[3], and a calibration certificate or report furnished to the waterworks.

UVT analyzer calibration is required when used as part of the calculated dose approach.[4] The UVT analyzer must be calibrated at least weekly by comparing on-line measurements to a bench top spectrophotometer that is calibrated in accordance with manufacturer's instructions. The calibration frequency may be decreased or increased based on the performance over a one year evaluation period.

Monthly Operation Reports should include a summary report of all UV sensor and/or UVT analyzer calibrations. Suggested calibration check logs are given in ATTACHMENT G. These should also be made available to VDH upon request, along with laboratory calibration certificates/reports (i.e. during the sanitary survey).

V. WATERWORKS CLASSIFICATION & OPERATOR REQUIREMENTS

As required in 12 VAC 5-590-460 A of the *Regulations*, "The waterworks operator license must be of a classification equal to or higher than that of the waterworks."

- Conventional treatment plants are minimum Class III, regardless of plant capacity, per the *Regulations*.
- Membrane filtration plants (typically used for GUDI sources) have a minimum designation of Class IV, per WM 880, regardless of plant capacity.
- The use of UV treatment devices for disinfection credit in all other cases shall require a plant designation of Class IV.[5]

VI. SPECIAL PERMIT REQUIREMENTS

Performance testing, should be included in the Special Permit Requirements of the Provisional Operation Permit. A template is provided in ATTACHMENT H, which is based on the *UV Disinfection Guidance Manual,* part 6.1.5 and Table 6.2.

Special Permit Requirements for UV Process Operations and reactor Shutdown shall be included in the standard Operation Permit for the waterworks. See ATTACHMENT I for template.

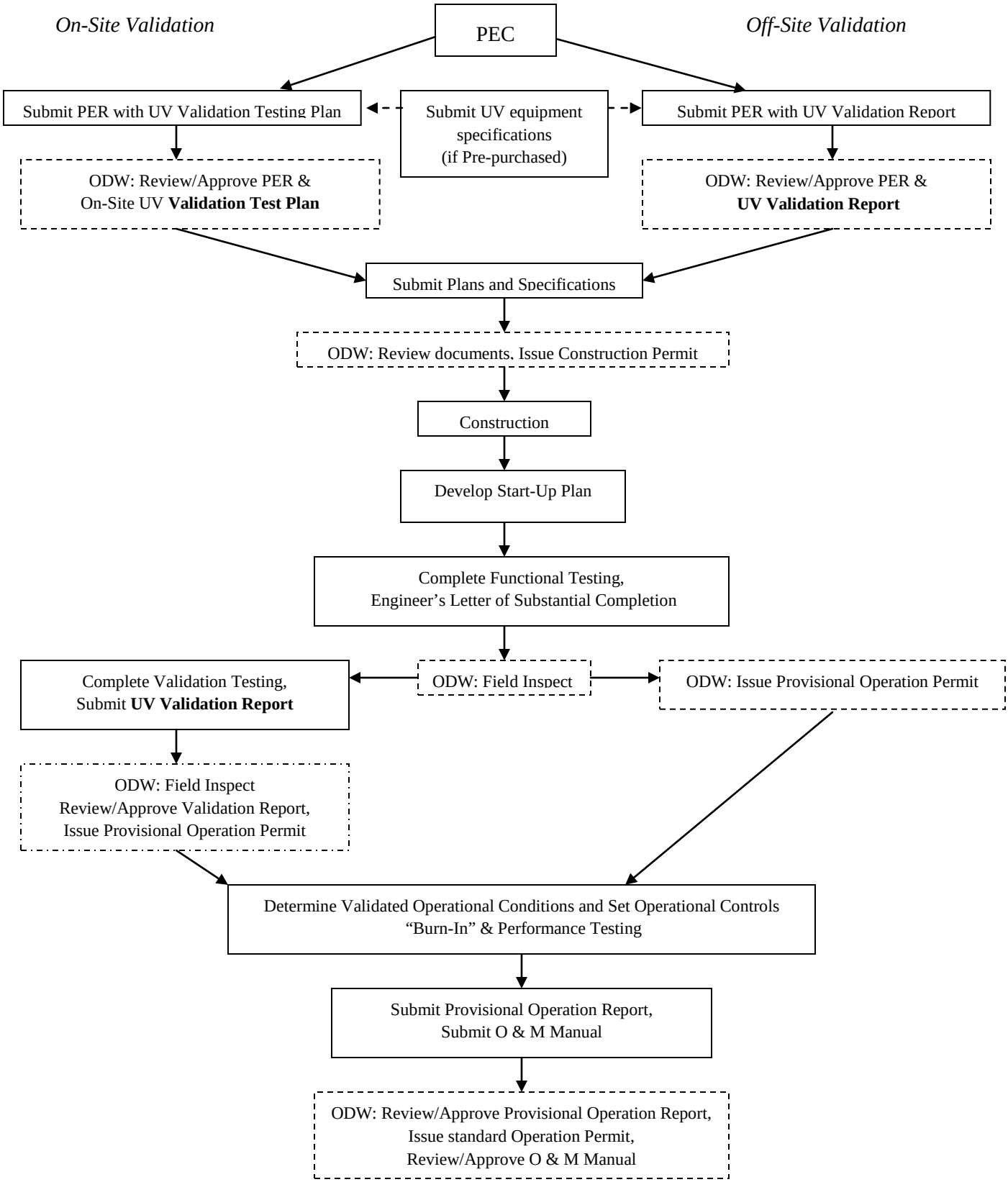
END OF MEMO

[3] Accreditation is recommended by Water Research Foundation, 2009. As of this memo date, accreditation has not been established.

[4] Section 6.4.1.2 of the UV Disinfection Guidance Manual provides recommended procedure for UVT analyzer calibration.

[5] Class IV waterworks are defined in the Regulations as serving < 5,000 persons or having a design hydraulic capacity of < 0.5 mgd, whichever is greater, employing approved treatment other than conventional filtration or fluoridation. This has been further modified by WM 842 and WM 841, which assigns Class V to plants serving 400 or more persons, and Class VI to those serving < 400 persons, if they (i) provide no treatment; or (ii) employ hypochlorination for disinfection; or (iii) employ corrosion control with calcite contactors and/or solution feed except with caustic; or are designated as such by the Commissioner.

APPENDIX A
UV TECHNOLOGY APPROVAL PROCEDURES FLOWCHART (for Disinfection Credit)



APPENDIX B
UV REQUIREMENTS FOR GROUNDWATER SYSTEMS – NO DISINFECTION CREDIT

BACKGROUND

The installation of UV disinfection equipment is sometimes considered in small, typically non-community groundwater systems, for the purpose of supplementing existing disinfection systems, and/or to provide some unspecified level of protection against microbial contamination.

This Appendix is dedicated to waterworks installing UV disinfection equipment which will NOT be given disinfection credit for *Giardia*, virus, or *Cryptosporidium*. If disinfection credit is sought in the future, the waterworks will have to address all of the requirements listed in the body of this working memo and the *Waterworks Regulations.*

All proposed systems used for the purpose stated above shall meet the requirements of NSF-55 Ultraviolet Microbiological Water Treatment Systems. This NSF standard identifies two classes of UV units, Class A and Class B. Class A devices are preferred.

APPROVAL PROCEDURES

The approval process for UV disinfection facilities where disinfection credit is not proposed is less involved than at those waterworks wanting disinfection credits. However, detailed information required in Section 8 of NSF-55 must be provided. A Preliminary Engineering Conference (PEC) is recommended, however a Preliminary Engineering Report (PER) may not be needed. The PEC and PER do not need to address Validation Testing and other reliability issues since disinfection credits will not be granted. Final design plans and specifications are required for VDH review and issuance of a Construction Permit. A standard Operation Permit will be issued upon completion of the project.

SPECIFIC DESIGN REQUIREMENTS

A. General

1. The UV reactor must be NSF-55 approved, and all other materials shall be NSF-61 approved.
2. The flow rate through the UV reactor must be limited to the rated flow rate of the NSF-55 certification.
3. Only one UV reactor is required.
4. Operating conditions must meet the NSF-55 required manufacturer's "Performance Data Sheet", including rated service flow, rated service life (gallons), maximum working pressure, maximum operating temperature, and service life of lamps.
5. UV reactor must be installed per manufacturer's recommendations.
6. A pressure gauge and air/vacuum release valve(s) must be installed, and are typically located upstream of the UV reactor.
7. Isolation valves and by-pass plumbing of the UV reactor must be provided.
8. The UV reactor must be accessible for visual observation, cleaning and replacement of the lamp, lamp jackets and sensor window/lens.
9. A water meter for the flow to the UV reactor is required, unless a raw water flow meter is already provided and it accurately measures the flow through the UV unit.
10. To obtain maximum benefit of UV disinfection, the raw water quality should meet the criteria recommended by Ten States Standards, described in Appendix C, item 3.

B. Facility Hydraulics

Common hydraulic issues associated with groundwater systems include high operating pressures, air entrainment, and water hammer. The engineer must evaluate worst case scenario for high pressure, which typically occurs when there is a downstream valve shut off. The maximum system pressure cannot exceed the maximum allowable pressure for the UV lamps. A water hammer surge analysis is recommended to determine the positive and negative pressure transients that may potentially break the sleeves and lamps. Surge protection (e.g. surge control tank) must be installed when determined necessary.

C. Instrumentation and Control

Continuous monitoring of UV lamp intensity and/or UV transmittance (UVT) is not required at groundwater systems not given disinfection credit. However, intensity or UVT monitoring is recommended in order to verify unit is operating within manufacturers design parameters.

An alarm system at these facilities is not required. However, the control system for the UV unit should include an automatic shutdown of the UV unit and the associated water pump feeding the unit in the event a lamp breaks while in service. This will prevent mercury from entering the distribution system.

D. Electrical Power Considerations and Back-up Power

Electrical power considerations related to providing a reliable and consistent source of power must be addressed. Back-up power is recommended but not required at groundwater systems not given disinfection credit.

MONITORING & REPORTING

Continuous monitoring of UV equipment is not required at groundwater systems not given disinfection credit. Monthly operation reports should include the operational status of the UV equipment during the month, the UV intensity/UV dose (if applicable), lamp cleaning dates, the manufacturer's lamp replacement interval, and the next scheduled lamp replacement date.

Groundwater sources equipped with UV disinfection must collect raw water MPN samples in accordance with ODW's *Compliance Sampling & Reporting Guidance Manual*.

WATERWORKS CLASSIFICATION & OPERATOR REQUIREMENTS

Community and Non-transient Noncommunity waterworks with groundwater sources that install UV equipment (and NOT receiving disinfection credit) will be designated Class V if they serve 400 or more persons, or Class VI if they serve < 400 persons. Transient Noncommunity waterworks will not be re-classified.

APPENDIX C
PRELIMINARY ENGINEERING CONFERENCE (PEC) & REPORT (PER)

The following topics should be discussed in the PEC, in addition to any other topics pertinent to the project. Further elaboration of these items is expected in the PER, which may be submitted following the initial conference. Refer to Chapters 3 and 4 of the *UV Disinfection Guidance Manual* for more detail on these subjects.

1. Summary of reasons for adding UV - Disinfection goals
   a. Identify target pathogen(s), target log-inactivation, and required UV dose.
   b. Provide details of the bioassay experiments and the procedure used to derive the operational UV dose.
   c. Submit a disinfection profile and benchmark. For systems which have already completed a profile, indicate the date the profile was completed and the benchmark.
2. Integration of UV into current treatment, with a schematic diagram of the complete water treatment facilities (including monitoring locations) and UV reactor location within the overall treatment scheme.
   a. Address effects of treatment upstream of UV – organics removal and chemicals affecting UV transmittance (ozone)
   b. Identify potential locations of UV equipment and discuss advantages and disadvantages of each location. For the locations selected, include a discussion on how the location will affect plant hydraulics, filter backwash cycles, accessibility of equipment and continuity of plant operations in the event of a lamp breakage or equipment failure
   c. Address changes in water quality after UV treatment – reduced residuals in pre-chlorinated water, increase in oxidation reduction potential (ORP)
3. Design Basis

   Identify key parameters in selecting equipment:

   a. Water quality parameters that may affect UV disinfection system performance and sleeve fouling/aging factor include UV transmittance (UVT), color, ORP, calcium, and alkalinity, as well as the following (values are recommended by Ten States Standards):

PARAMETER	VALUE
Dissolved Iron	< 0.3 mg/L
Dissolved Manganese	< 0.05 mg/L
Hardness	< 120 mg/L
Hydrogen sulfide (if odor is present)	Non-Detectable
Iron Bacteria	None
pH	6.5 to 9.5
Suspended Solids	< 10 mg/L
Turbidity	< 1.0 NTU*

* < 5.0 NTU is generally accepted by the industry

UVT may vary with flow rate, so a matrix of values may be appropriate. Parameters must be representative of water entering the UV reactor(s).

Sand particles may be common in some wells and means to prevent sand from scratching or breaking the lamp sleeves should be included in the facility design. Common methods for reducing sand contact with the UV reactor are installation of a sand/debris trap, cartridge filters, and/or wasting well water at well start-up.

b. Flow rates: average, maximum and minimum- experienced by the UV reactors

c. Evaluation of the number of power quality events occurring per month at the site. UV lamps can lose arc due to voltage fluctuation, power interruption or power quality anomaly. A separate power quality assessment is required if the site has significant interruptions and/or brownouts per month (on the order of 30 events) or is located in a remote area and the power quality is unknown.

d. Off-specification operation. At least 95% of water delivered to public each month must be treated by UV reactors operating within validated limits. List conditions under which UV reactors would be off-spec.

4. Control Strategy and Reactor Validation Approach (Validation Test Plan)[6]

   a. Identify dose monitoring strategy and parameters monitored to confirm dose delivery. For the calculated dose strategy, an explanation of how the equation was developed must be included.

   b. Explain whether validation will be on-site or off-site. For off-site validation, a copy of the validation report must be included in the PER or with the technical specifications. For on-site validation, include a description of the proposed validation procedures and facility design.

5. Layout and Hydraulics

   a. Reactor and reactor train layout and dimensions, inlet and outlet configuration, reactor train velocity range, and any devices used to modify the flow within the pipes or channels

   b. The water level relative to the UV lamps and level control device;

   c. The anticipated number of reactor trains in operation under low and peak flow conditions and the corresponding inlet and outlet velocity ranges

   d. Head loss through UV facility and available head downstream

6. UV Equipment

   a. Description of the UV reactor; number, manufacturer and type of UV lamps (including arc length); ballast; modules; banks; and electrical facilities

   b. Sleeve configuration and characteristics (e.g.-sleeve material, sleeve diameter, sleeve thickness, and spacing)

   c. Cleaning system

7. Instrumentation and Controls

[6] Some testing organizations have pre-approved Validation Test Plans, and only a Validation Report is required.

a. The equipment and procedures used to monitor and record the operational UV dose, flow rate, UV lamp intensity, UV transmittance

b. The method of monitoring the water level

c. The method of monitoring lamp status

8. Reliability

   Describe the proposed UV disinfection system reliability features in detail to insure the continuous operability of the system. The report must include: where the alarm(s) will be received, how the location is staffed, who will be notified, the hours that the plant will be staffed, an evaluation of the plant power supply.

9. Contingency Plan

   Provide a contingency plan that delineates the actions to be taken for the following conditions:

   a. Lamp breakage (mercury release, amount of mercury per lamp and containment),

   b. Low operational UV dose, low UV intensity, and/or high turbidity alarms,

   c. Failure of the upstream treatment processes (ozone destruct units, organics removal, etc.) or the UV disinfection system, and

   d. Power supply interruptions.

The person(s) responsible for implementing the contingency plan must be identified along with methods used to notify them.

ATTACHMENTS

NOTE: These attachments are posted to ODW internal server under..\..\..\..\..\03-Memos\301-Active Working Memos\301.02-Forms Letters Manuals

ATTACHMENT A
ULTRAVIOLET (UV) DISINFECTION PROJECT REVIEW FORM

ATTACHMENT B
CONTENT OF UV EQUIPMENT SPECIFICATIONS
(Table 4.3 EPA Guidance Manual)

ATTACHMENT C
UV REACTOR DOCUMENTATION FOR VALIDATION TEST
(Checklist 5.1 EPA Guidance Manual)

ATTACHMENT D
UV VALIDATION TEST PLAN CONTENTS
(Checklist 5.2 EPA Guidance Manual)

ATTACHMENT E
UV VALIDATION TEST REPORT REVIEW
(*Checklist 5.3 & 5.5 EPA Guidance Manual)*

ATTACHMENT F
ON-SITE VALIDATION TESTING REVIEW OF QUALITY ASSURANCE/QUALITY CONTROL
(Checklist 5.4 EPA Guidance Manual)

ATTACHMENT G
MONTHLY OPERATION REPORT FORMS
(Figs. 6.2 through 6.8 EPA Guidance Manual – Excel file)

- UV Reactor Operation Summary
- UV Operation Log - Calculated Dose Control
- UV Operation Log - UV Intensity Setpoint Control
- UV Operation: Off-Spec Calculation Worksheet
- UV Sensor Calibration Report
- UV Sensor Correction Factor (CF) Worksheet
- UVT Analyzer Calibration Check Log

ATTACHMENT H
SPECIAL UV PERMIT REQUIREMENTS DURING PROVISIONAL OPERATING PERIOD (Including UV Performance Testing)

ATTACHMENT I
SPECIAL UV PERMIT REQUIREMENTS - STANDARD OPERATION PERMIT

ULTRAVIOLET (UV) DISINFECTION
PROJECT REVIEW FORM

Waterworks: _____ Reviewer: _____
Project Title: _____ Date: _____

DESIGN BASICS (Refer to APPENDIX C of WM 839 – PRELIMINARY ENGINEERING)	
1. Disinfection Goals	
2. UV Process Location ("after conventional filters", etc.)	
3. Water Quality (Influent)	
Flow Rate(s)	
4. Control Strategy	☐ Calculated Dose Control ☐ UV Intensity Set Point Control
5. UV Reactors (pre-selected or pre-purchased)	Manufacturer & Model No.: Type of UV Units: ☐ Low Pressure ☐ Medium Pressure UV Reactor Specifications Submitted? ☐ Yes ☐ No If yes, Complete WM 839-ATTACHMENT B
6. Reactor Validation	☐ On-site ☐ Off-site
Validation Test Plan / Protocols	Validation Test Plan Submitted? ☐ Yes ☐ No [required for on-site validation] If yes, Complete WM 839-ATTACHMENT C, D
Validation Report	Complete WM 839-ATTACHMENT E, F (if on-site)
7. Layout & Hydraulics	No. of Reactors (min. 2): _____ Reactor Arrangement (Schematic):
8. Instrumentation & Controls	
9. Reliability	
10. Contingencies	

WM839 ATTACHMENTS included:

☐ B- UV Equipment Specs Review (Table 4.3 *EPA Guidance Manual*)
☐ C- UV Reactor Documentation for Validation Test (Checklist 5.1 *EPA Guidance Manual*)
☐ D- UV Validation Test Plan Content Review (Checklist 5.2 *EPA Guidance Manual*)
☐ E- UV Validation Test Report Review (Combined Checklists 5.3 & 5.5 *EPA Guidance Manual*)
☐ F- On-Site UV Validation QA/QC (Checklist 5.4 *EPA Guidance Manual*)

FINAL DESIGN

UV Control Strategy:

Units Using **Intensity Set Point Control System**

No. of Inline UV Intensity Sensors:____ (No. based on Validation Testing)

Required UV Intensity for Disinfection Credits:_____ W/m^2

Low UV Intensity Alarm/Shutdown Set Point Provided in Specifications:_____ W/m^2

Reference Intensity Sensor(s) Provided: ☐ Yes ☐ No No. provided:_____

UV Intensity Sensor Recorder(s) Provided For Reactor(s): ☐ Yes ☐ No

Units Using **Calculated Dose Control System**

No. of Inline UV Transmittance (UVT) Analyzers/Reactor:____ (No. based on Validation Testing)

Required Dose/Reactor for Disinfection Credits: _____ mJ/cm^2

Low UVT Alarm/Shutdown Set Point Recommended in Specifications:_____ %

Low Calculated Dose Alarm/Shutdown Shutdown Set Point Provided:_____ mJ/cm^2

UVT Analyzer Recorder(s) Provided For Reactor(s): ☐ Yes ☐ No

Laboratory Equipment: Bench UV Spectrophotometer Provided ☐ Yes ☐ No

UV Reactor Appurtenances

Upstream and Downstream Isolation Valves/Reactor ☐ Yes ☐ No

Feed Pumps ☐ Yes ☐ No ☐ NA

No. of Feed Pumps:____

Feed Pump Capacity:_____ gpm/ft TDH (Review Design of pump and pump appurtenances)

Flow Meter/Reactor (Recommend High Flow Rate Alarm) ☐ Yes ☐ No

Air Release and Vacuum Relief Valves Provided ☐ Yes ☐ No

Ground Fault Interrupt Circuit Provided For Lamps ☐ Yes ☐ No

Sample Taps (Upstream/Downstream each Reactor) ☐ Yes ☐ No

Drains at each reactor ☐ Yes ☐ No

Safety Glasses Provided ☐ Yes ☐ No

Lamp Cleaning System ☐ Automatic ☐ Manual

Manual Cleaning systems should provide rack for cleaning bulbs ☐ Yes ☐ No ☐ NA

Automatic Wiper Systems should provide wiper failure alarm ☐ Yes ☐ No ☐ NA

Water Level Sensor/Reactor with Automatic Shutoff ☐ Yes ☐ No

Lamp/Lamp Ballast Failure Sensor & Automatic Shutoff/Reactor ☐ Yes ☐ No

High Temperature Sensor/Reactor with Automatic Shutoff ☐ Yes ☐ No

Adequate Spare Parts Inventory ☐ Yes ☐ No ☐ NA

Content of UV Equipment Specifications

Item	Specification Content
Flow rate	Maximum, minimum, and average flow rates should be clearly identified. The maximum flow rate must be within the validated range documented in the validation report [40 CFR 141.720 (d)(3)]. The minimum flow rate may be important to avoid overheating with MP reactors.
Target Pathogen(s) and Log Inactivation	The log inactivation for the target pathogen(s)
Required UV Dose	The required UV dose for the target microorganism and log inactivation that must be verified by the validation process.
Water Quality and Environment	The following water quality criteria should be included: Influent Temperature, pH, Turbidity, Iron, UV transmittance at 254 nm Calcium, UVT scan from 200 – 300 nm (MP reactors only), Manganese, ORP, Total Hardness For some parameters, a design range may be most appropriate.
Operating Flow and UVT Matrix	Appropriate matrix of paired flow and UVT values based on flow and UVT data.
Operating Pressure	The expected operating pressures, including the maximum and minimum operating pressure to be withstood by the lamp sleeves and UV reactor housing.
UV Sensors	A germicidal spectral response should be specified. A minimum of one UV sensor should be specified per UV reactor. The actual number should be identical to the UV reactor that was, or will be, validated. The uncertainty of the UV sensors used during **validation** should meet the criteria described in the UV Guidance Manual (Section 5.5.4). The uncertainty of the duty UV sensors during **operation** should meet the criteria described in the UV Guidance Manual (Section 6.4.1.1). Reference UV sensors should be calibrated against a traceable standard.
Redundancy	Capacity provided with the largest UV reactor out-of-service required. Power modulation capabilities of the UV reactor should be determined.
Hydraulics	The following hydraulic information should be specified: - Maximum system pressure at the UV reactor - Maximum allowable head loss through the UV reactor - Special surge conditions that may be experienced - Hydraulic constraints based on site-specific conditions and validated conditions (e.g., upstream and downstream straight pipe lengths).
Size/Location Constraints	Any size constraints or restrictions on the location of the UV reactor or control panels (e.g., space constraints with individual filter effluent installation).
Validation	The range of operating conditions (e.g., flow, UVT) that must be included in the validation testing, and submittal of a validation report (40 CFR 141.720) are required.
Dose-Monitoring Strategy	A description of the preferred dose-monitoring strategy for the UV reactors.
Operating Approach	A description of the intended operating approach for the UV reactors.
Economic and Non-Economic Factors	Information to thoroughly evaluate the UV equipment based on the PWS's specific goals. Economic factors include energy use, chemical use; non-economic factors may include future expansion, manufacturer experience.

Lamp Sleeves	Lamp sleeves should be annealed to minimize internal stress.
Safeguards	At a minimum, the following UV reactor alarms should be specified: - Lamp or ballast failure - Low UV intensity or low validated UV dose (depending on dose-monitoring strategy used) - High temperature - Operating conditions outside of validated range - Wiper failure (as applicable) - Other alarms discussed as appropriate.
Instrumentation and Control	At a minimum the following signals and indications should be specified: - UV lamp status - UV reactor status - UV intensity - Lamp cleaning cycle and history - Accumulated run time for individual lamps or banks of lamps - Influent flow rate. At a minimum the following UV reactor controls should be specified: - UV dose setpoints, UV intensity setpoints, or UVT setpoints (depending on dose-monitoring strategy used) - UV lamps on/off - UV reactor on/off control - UV reactor manual/auto control - UV reactor local/remote control - Manual lamp power level control - Manual lamp cleaning cycle control - Automatic lamp cleaning cycle setpoint control.
Performance Guarantee	The following specific performance criteria may be included: - Allowable head loss at each design flow rate - Estimated power consumption under the design operating conditions - Disinfection capacity of each reactor under the design water quality conditions - Sensitivity of equipment to variations in voltage or current - Reference UV sensor, duty UV sensor, and UVT analyzer (if provided) performance compared to specification
Warranties	The specific requirements of these guarantees will be at the discretion of the PWS and engineer. Lamps should be warranted to provide the lamp intensity under the design conditions for the fouling/aging factor and a minimum number of operating hours. To limit the UV manufacturer's liability, the guarantee could be prorated after a specified number of operating hours.
UVT Analyzer	During operation, the difference between the UVT analyzer measurement and the UVT measured by a calibrated spectrophotometer should be less than or equal to 2 % UVT.

UV Reactor Documentation for Validation Test

Does UV reactor documentation contain the following elements?

YES NO

General

☐ ☐ Technical description of the reactor's UV dose-monitoring strategy, including the use of sensors, signal processing, and calculations (if applicable).

☐ ☐ Dimensions and placement of all wetted components (e.g., lamps, sleeves, UV sensors, baffles, and cleaning mechanisms) within the UV reactor.

☐ ☐ A technical description of lamp placement within the sleeve.

☐ ☐ Specifications for the UV sensor port indicating all dimensions and tolerances that impact the positioning of the sensor relative to the lamps. If the UV sensor port contains a monitoring window separate from the sensor, specifications giving the window material, thickness, and UV transmittance should be provided.

Lamp specifications

☐ ☐ Technical description
☐ ☐ Lamp manufacturer and product number
☐ ☐ Electrical power rating
☐ ☐ Electrode-to-electrode length
☐ ☐ Spectral output of new and aged lamps (specified for 5 nm intervals or less over a wavelength range that includes the germicidal range of 250 - 280 nm and the response range of the UV sensors)
☐ ☐ Mercury content
☐ ☐ Envelope diameter

Lamp sleeve specifications

☐ ☐ Technical description including sleeve dimensions
☐ ☐ Material
☐ ☐ UV transmittance (at 254 nm for LP and LPHO lamps, and at 200 - 300 nm for MP lamps with germicidal sensors)

Specifications for the reference and the duty UV sensors

☐ ☐ Manufacturer and product number
☐ ☐ Technical description including external dimensions
☐ ☐ Data and calculations showing how the total measurement uncertainty of the UV sensor is derived from the individual sensor properties.

UV Reactor Documentation for Validation Test

Does UV reactor documentation contain the following elements?

YES NO

Sensor measurement properties

YES	NO	
☐	☐	Working range
☐	☐	Spectral and angular response
☐	☐	Linearity
☐	☐	Calibration factor
☐	☐	Temperature stability
☐	☐	Long-term stability

Specifications for the reference and the duty UV sensors

YES	NO	
☐	☐	Flow rate, head loss, and pressure rating of the reactor
☐	☐	Assembly and installation instructions
☐	☐	Electrical requirements, including required line frequency, voltage, amperage, and power
☐	☐	Operation and maintenance manuals that include cleaning procedures, required spare parts, and safety requirements. Safety requirements should include information on electrical lockouts, eye and skin protection from UV light, safe handling of lamps, and mercury cleanup recommendations in the event of lamp breakage.

UV Validation Test Plan Contents

Does the validation test plan contain the following elements?

YES	NO	
☐	☐	Purpose of Validation Testing. General description of why the tests are being done and how the data will be used.
☐	☐	Roles and Responsibilities. Key personnel overseeing and performing the full-scale reactor testing and collimated beam testing, including their qualifications. Include contact names and telephone numbers.
☐	☐	Locations and Schedule. Location for conducting full-scale reactor testing and collimated beam testing, and schedule for conducting the tests and performing the data analyses.
☐	☐	Challenge Microorganism Specifications. Specifications for the challenge microorganism to be used during validation that include the protocols required for growth and enumeration, the expected UV dose-response, and suitability for use in validation testing.

Design of the Biodosimetry Test Stand/On-site Testing Facilities

☐	☐	Inlet/outlet piping design, including backflow prevention
☐	☐	Mixing
☐	☐	Sample ports
☐	☐	Pumps
☐	☐	Additives (Material Safety Data Sheets for UV-adsorbing chemical, quenching agent)

Collimated Beam Testing Apparatus

☐	☐	Lamp type
☐	☐	Collimating tube aperture
☐	☐	Distance from light source to sample surface
☐	☐	Radiometer make and model

Monitoring Equipment Specifications and Verification of Equipment Accuracy for the following:

☐	☐	Flow meter
☐	☐	UVT analyzer (if used)
☐	☐	UV Spectrophotometers
☐	☐	Power measurement
☐	☐	UV sensor
☐	☐	Radiometer make, model, and calibration certificates

Experimental Test Conditions including, but not limited to:

☐	☐	Number of tests, UVT, flow rate, lamp power, and lamp status for each test condition
☐	☐	Lamp fouling factor, use of new or aged lamps
☐	☐	Influent concentration of challenge microorganisms for each test condition
☐	☐	QA/QC Plan

UV Validation Test Report Review

YES NO

General

☐ ☐ Detailed reactor documentation including drawings and serial numbers, and procedures used to verify reactor properties.

☐ ☐ Validation test plan (either a summary of key elements, or the test plan can be attached to the validation report along with documentation of any deviations to the original test plan)

Full-scale reactor testing results, with detailed results for each test condition evaluated. Data should include, but are not limited to:

☐ ☐ Flow rate

☐ ☐ Measured UV intensity

☐ ☐ UVT

☐ ☐ Lamp power

☐ ☐ Lamp statuses

☐ ☐ Inlet and outlet concentrations of the challenge microorganism

Collimated beam testing results, including detailed results for each collimated beam test used to create the UV dose-response equation:

☐ ☐ Volume and depth of microbial suspension

☐ ☐ UV Absorption of the microbial suspension

☐ ☐ Irradiance measurement before and after each irradiation

☐ ☐ Petri factor calculations and results

☐ ☐ Calculations for UV dose

☐ ☐ Derivation of the UV dose-response equation, including statistical methods and confidence intervals (i.e., calculation of U_{DR})

QA/QC Checks:

☐ ☐ Challenge microorganism QA/QC, including blanks, controls, and stability analyses

☐ ☐ Measurement uncertainty of the radiometer, date of most recent calibration, results of reference checks

☐ ☐ Measurement uncertainty of UV sensors and results of reference checks

☐ ☐ Measurement uncertainty of the flow meter, UV spectrophotometer, and any other measurement equipment used during full-scale testing

Calculation of the validated dose, log inactivation credit, and validated operating conditions:

☐ ☐ RED for each test condition

☐ ☐ Calculation of the VF

☐ ☐ Setpoints if the reactor uses the UV Intensity Setpoint Approach

☐ ☐ Dose-monitoring equation if the reactor uses the Calculated Dose Approach

☐ ☐ Log inactivation credit for target pathogens (e.g., *Cryptosporidium, Giardia,* and viruses)

☐ ☐ Validated operating conditions (e.g., flow rate, lamp status, UVT)

YES	NO	
☐	☐	Does the validation testing meet QA/QC criteria?
☐	☐	For full-scale testing, is the mixing and location of sample ports acceptable?
☐	☐	If the reactor was validated off-site, do inlet/outlet piping conditions at the water treatment plant result in a UV dose-delivery that is **the same or greater than** the UV dose delivery at the off-site testing facility?
☐	☐	Were collimated beam tests and full-scale reactor tests performed on the same day for a given test condition and using the same stock solution of challenge microorganisms?
☐	☐	Is the UV sensitivity of the challenge microorganism and the overall shape of the UV dose-response curve consistent with the expected inactivation behavior for that challenge microorganism?
☐	☐	Does the validation test design account for lamp fouling and aging, minimum UVT, and maximum flow rate expected to occur at the water treatment plant?

For UV Reactors Using MP Lamps

☐	☐	Is the UV reactor equipped with a germicidal sensor? New UV reactors should have germicidal sensors. If an installed reactor uses an MP lamp and a non-germicidal sensor, is a polychromatic bias factor incorporated into the derivation of the VF?
☐	☐	Was validation testing conducted using a challenge microorganism other than MS2 or *B. Subtilis?* If yes, was the need for a correction factor assessed and was that factor applied based on the outcome?

For UV Reactors Using the UV Intensity Setpoint Approach

☐	☐	Were the minimum test conditions performed as specified?
☐	☐	Is the UV intensity setpoint low enough to account for combined conditions of minimum UVT and maximum lamp fouling/aging at the water treatment plant
☐	☐	Was the **minimum RED** selected for calculating the validated dose?
☐	☐	Does the VF calculation include both the B_{RED} and U_{sp}?
☐	☐	If U_s and/or U_{DR} did not meet the QA/QC criteria, were they also included in the VF calculation?
☐	☐	Is the validated dose greater than or equal to the required dose for the water system's target pathogen and log inactivation level?

For UV Reactors Using the Calculated Dose Approach

☐	☐	Was the minimum number of test conditions evaluated as specified?
☐	☐	Was the empirical equation developed using standard statistical methods (e.g., multivariate linear regression)?
☐	☐	Does the validation report include an analysis of goodness of fit and bias for the dose-monitoring equation?
☐	☐	Does the VF calculation include both the B_{RED} and U_{IN}?
☐	☐	If U_s and/or U_{DR} did not meet the QA/QC criteria, were they also included in the VF calculation?
☐	☐	For the range of UVT values and flow rates expected to occur at the water system, is the validated dose greater than or equal to the required dose for the system's target pathogen and log inactivation?

On-Site Validation Testing
Review of Quality Assurance/Quality Control

YES NO

Uncertainty in Measurement Equipment

☐ ☐ **Flow Meter:** Is the measurement uncertainty < 5 %?

☐ ☐ **UV Spectrophotometer:** Is the measurement uncertainty ≤ 10 %?

☐ ☐ **UV Sensors:** Did duty sensors operate within 10 % of the average of two or more reference sensors? If not, was uncertainty in sensor measurement incorporated into the VF?

☐ ☐ **Radiometer:** (for collimated beam testing only). Do lamp output measurements vary by no more than 5 % over exposure time? Was the accuracy of the radiometer verified with another radiometer?

QA/QC of Microbial Samples

☐ ☐ **Reactor controls:** For influent/effluent samples taken with the UV reactor lamps turned off, does the change in log concentration correspond to a change in RED that is within the measurement error of the minimum RED measured during validation (typically ≤ 3 %)?

☐ ☐ **Reactor blanks:** For DAILY influent/effluent samples taken with NO challenge microorganisms injected, are the measured concentrations of the challenge microorganism negligible?

☐ ☐ **Trip Controls:** For an UNTESTED sample bottle of challenge microorganism stock solution that travels with tested samples between the laboratory and the reactor, is the change in the log concentration of the challenge microorganism within the measurement error. (I.e., the change in concentration over the test run should be negligible. This is typically on the order of 3 - 5%.)

☐ ☐ **Method Blanks:** For sterilized reagent grade put through the challenge microorganism assay procedure, is the challenge microorganism concentration non-detectable?

☐ ☐ **Stability Samples:** For influent/effluent samples at low and high UVT, are the challenge microorganism concentrations within 5 % of each other?

Uncertainty in Collimated Beam Testing Data

☐ ☐ Do the uncertainties in the terms in the UV dose calculation meet the following criteria:

- Depth of suspension (d) ≤ 10 %
- Incidence irradiance (E_s) ≤ 8 %
- Petri factor (P_f) ≤ 5 %
- L/(d + L) ≤ 1 %
- Time (t) ≤ 5 %
- $(1 - 10^{-ad})/ad$ ≤ 5 %

☐ ☐ Is the **uncertainty in dose-response** (U_{DR}), as calculated, less than or equal to 30 %? If not, was U_{DR} incorporated into the VF?

Facility Name
PWSID #
No. Connections Served:
Population Served:
Month Year

UV Reactor Operation Summary

			Off-Specification Data	
Unit Number	Total Run Time (hrs)	Total Production (MG)	Number of Off-Specification Events	Total Off-Specification Volume (MG)
Total	0.0	0.0	0.0	0.0

Reactor Number	Sensor Correction Factor

Compliance Certification

Total Volume of Off-Specification Water Produced (MG) [A]	0.0
Total Volume of Water Produced (MG) [B]	0.0
Total Off-Specification Water Produced (% of Volume of Water Produced) ([A]/[B]*100)	#DIV/0!
Facility Meets Off-Specification Requirement (< 5% of Volume on a Monthly Basis)	#DIV/0!
Of the _____ sensors, _____ have been checked for calibration and were withing the acceptable range of tolerance.	

UV OPERATION LOG - CALCULATED DOSE CONTROL

Maximum Validated Flow Rate:
Minimum Validated UVT:
Target Log Inactivation:
UV Reactor: Target Pathogen:
Process Train: Dose Required ($D_{req'd}$):
Validation Factor (VF):

Validated Dose = Calculated Dose / (VF x CF)

Calculated Dose =Dose that is calculated by validated PLC algorithm
VF = Validation factor
CF = UV intensity sensor correction factor.
(The CF is only applied if sensors do not meet recommended criteria; CF will not be needed in most cases.)

Operational Data			Dose Requirements	Data at Daily Minimum Validated Dose					UV Dose Adequacy Determination	Total Off-Specification
Date	Run Time (hrs)	Total Production (MG)	$D_{req'd}$[1] (mJ/cm^2) [A]	Sensor Correction Factor[2] [B]	Calculated Dose[3] (mJ/cm^2) [C]	Daily Minimum Validated Dose[4] ([C]/[VF]/[B]) (mJ/cm^2) [D]	Flow Rate (MGD)	UVT (%)	Validated Dose > $D_{req'd}$ ([D] > [A]) (Y/N)	Total Off-Specification Volume (MG)
1						#DIV/0!			#DIV/0!	
2						#DIV/0!			#DIV/0!	
3						#DIV/0!			#DIV/0!	
4						#DIV/0!			#DIV/0!	
5						#DIV/0!			#DIV/0!	
6						#DIV/0!			#DIV/0!	
7						#DIV/0!			#DIV/0!	
8						#DIV/0!			#DIV/0!	
9						#DIV/0!			#DIV/0!	
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28						#DIV/0!			#DIV/0!	
29						#DIV/0!			#DIV/0!	
30						#DIV/0!			#DIV/0!	
31						#DIV/0!			#DIV/0!	
Min	0.0	0.00	0.0	0	0.0	#DIV/0!	0.00	0.0		
Max	0.0	0.00	0.0	0	0.0	#DIV/0!	0.00	0.0		
Total	0.0	0.00								0.00

UV OPERATION LOG - UV INTENSITY SETPOINT CONTROL

Maximum Validated Flow Rate:
Minimum Validated UVT:
Target Log Inactivation:
UV Reactor: Target Pathogen:
Process Train: Intensity Setpoint:

Operational Data						Intensity Requirements			Daily Minimum Intensity		Total Flow Off-Specification
			Flow Rate								
Date	Run Time (hrs)	Total Production (MG)	Min (mgd)	Ave (mgd)	Max (mgd)	Intensity Setpoint (W/m^2) [A]	Sensor Correction Factor[1] [B]	Adjusted Intensity Setpoint (W/m^2) ([A] * [B]) [C]	Daily Minimum Intensity (W/m^2) [D]	Minimum Daily Intensity > Adjusted Intensity Setpoint ([D] > [C]) (Y/N)	Total Flow Off-Specification[3] (MG)
1								0.0		No	
2								0.0		No	
3								0.0		No	
4								0.0		No	
5								0.0		No	
6								0.0		No	
7								0.0		No	
8								0.0		No	
9								0.0		No	
10								0.0		No	
11								0.0		No	
12								0.0		No	
13								0.0		No	
14								0.0		No	
15								0.0		No	
16								0.0		No	
17								0.0		No	
18								0.0		No	
19								0.0		No	
20								0.0		No	
21								0.0		No	
22								0.0		No	
23								0.0		No	
24								0.0		No	
25								0.0		No	
26								0.0		No	
27								0.0		No	
28								0.0		No	
29								0.0		No	
30								0.0		No	
31								0.0		No	
Min	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0		
Max	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0		
Total	0.0	0.00									0.00

[1] Sensor CF will be 1 is no CF is used.

[2] UVT measurements are not required but could be useful in addressing operational issues.

[3] Off-specification Worksheet K should be used to calculate daily off-specification volume. If UV intensity or flowrate off-specification occur simultaneously, the off-specification time should only be counted once

UV OPERATION: OFF-SPEC CALCULATION WORKSHEET

Date[1]	Reactor Number	Process Train Number	Off-Specification Event Description[2]	Flow Rate[3] (MGD) [A]	Time (days) [B]	Off-Specification Volume (MG) ([A]*[B])
						0.00
						0.00
						0.00
						0.00
						0.00
						0.00
						0.00
						0.00
					Total Off-Specification Flow for the Day[4]	0.00

[1] This workseet should only be used for one date and one reactor.

[2] This worksheet assumes that the flowrate is constant during the off-specification event. Off-specification volume can also be obtained from a flow totalizer.

[3] Off-Specification event can be caused by UVT, flowrate, intensity, or validated dose being out of the validated range.

[4] The total off-specification flow should be transferred to Worksheet J if any off-specification events occurred.

UV SENSOR CALIBRATION REPORT

Calibration Ratio = $\left(\frac{S_{Duty}}{S_{Ref}}\right)$ where S is the measured intensity

Sensor Correction Factor = $\left(\frac{S_{Duty}}{S_{Ref}} - 0.2\right)$

Sensor Correction Factor (CF) used (if applicable) =

	Reactor Number	Duty Sensor Number	UV Sensor Operating Time (hrs)	Reference Sensor Serial Number	Duty UV Sensor Reading[1] [A]	Reference UV Sensor Reading[1] [B]	Calibration Ratio ([A]/[B])	Calibration Ratio ≤ 1.2 (Y/N)	Sensor Correction Factor Used	If CF is used, Calibration Ratio - 0.2 ≤ CF (Y/N)
Date							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		
							#DIV/0!	#DIV/0!		

Certification:

Number of UV sensor calibrated _____

Number of UV sensors out of calibration _____

Number of UV sensor(s) sent to manufacturer to be recalibrated as documented below _____

UV intensity sensors sent to manufacturer for calibration (Add additional rows as necessary):

	Unit No.	Date Sent	Date Received
Sensor Serial Number			

UV SENSOR CORRECTION FACTOR (CF) WORKSHEET (Optional)

CF used (if applicable)=

$$\text{Correction Factor} = \left(\frac{S_{Duty}}{S_{Ref}} - 0.2 \right)$$

Where:

S_{Duty} is the duty UV sensor reading

S_{Ref} is the duty UV sensor reading

Date	Reactor Number	Duty Sensor Number[1]	UV Sensor Operating Time (hrs)	Reference Sensor Serial Number	Duty UV Sensor Reading[3] [A]	Reference UV Sensor Reading[3] [B]	Sensor Correction Factor (([A]/[B])-0.2)
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
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							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
							#DIV/0!
					Selected UV Sensor CF[2]		

[1] Only failed sensors need to be input.

[2] UV Sensor CF should be based on the calibration ratios for the failed sensors and should use the maximum ratio. The CF is reactor specific.

[3] If three duty UV sensor and reference UV sensor readings are taken, the mean of the reading can be used.

UVT Analyzer Calibration Report (Make Additional Copies of Form as Necessary)

UVT Analyzer Number	Week Number	Dates	On-line Reading (%) [A]	Grab Sample Result (%) [B]	Difference (%) (|[A]-[B]|)	Difference ≤ 2% UVT? (Y/N)
	1				0	Yes
	2				0	Yes
	3				0	Yes
	4				0	Yes
	5				0	Yes

Certification:

All calibration checks were within the acceptable tolerance during this month. ☐

Recalibration was required and is documented below. ☐

On-Site Calibration. ☐ Manufacturer Calibration. ☐

UVT Analyzer Calibration

UVT Analyzer Number	On-site or manufacturer recalibration?	Date Recalibration Performed	Recalibration Successful? (Y/N)	Initials (On-site Calibration Only)

SPECIAL UV PERMIT REQUIREMENTS DURING PROVISIONAL OPERATING PERIOD

SPECIAL PERMIT REQUIREMENTS

Waterworks Name
PWSID No. ######

These Permit Requirements are issued by the State Board of Health of the Commonwealth of Virginia under authority granted by Title 32.1 of the *Code of Virginia.* Failure to comply with these Requirements shall constitute a violation of the Permit.

UV Performance Testing

At the beginning of the provisional operating period, the equipment must undergo a 100 hour burn-in period, followed by a minimum 4 weeks of performance testing in order to confirm operation within validated settings. Monitoring during performance testing must include: *(Select those that apply and see part 6.1.5 and Table 6.2, UV Disinfection Guidance Manual for others parameters)*

PARAMETER	Monitoring Frequency	Purpose
UV Intensity *(those using single UV Intensity setpoint control)*	Continuous	To confirm compliance with setpoints established during validation.
UV Dose *(those using calculated dose control)*	Continuous	To confirm compliance with setpoints established during validation.
Power Consumption	Continuous	To determine if energy efficiency improvements can be made within the validation requirements
UV Sensor Calibration *(those using single UV Intensity setpoint control)*	Weekly	Check the duty UV sensor against reference UV sensor to determine whether the duty UV sensor is in calibration
UVT Analyzer Calibration *(those using calculated dose control)*	Weekly	Compare on-line UVT analyzer results to UVT results using the bench-top spectrophotometer
Switch to Standby Reactor	Twice during Performance Testing	To establish time necessary to switch to a standby reactor in order to avoid off-specification operation.
Switch to Standby Power or UPS	Twice during Performance Testing	To establish time necessary to switch to a standby power or UPS in order to avoid off-specification operation.
Inspect Lamp Sleeve for Fouling	End of Performance Testing	To establish cleaning frequency of lamp systems

Submit Functional Testing Report for UV Reactors within 30 days of completion of Performance Testing.

SPECIAL UV PERMIT REQUIREMENTS DURING PROVISIONAL OPERATING PERIOD

UV Reactor Operational Limits and UV Equipment Alarm Criteria (covers entire provisional period)
(Based on values established during validation of UV Reactor. These values may have to revised based on Functional Testing Report)

UV REACTOR PARAMETER	MINIMUM REACTOR OPERATIONAL LIMIT (ALARM REQUIRED)
UV Intensity *(those using single UV Intensity setpoint control)*	_____W/m^2
UV Dose *(those using calculated dose control)*	_____mJ/cm^2

UV REACTOR PARAMETER	ALARM CRITERIA
High Flow Rate	gpm
Low UV Transmittance *(those using calculated dose control)*	% UVT
Lamp/Ballast Failure	
High Temperature	^0C
Mechanical Wiper Failure *(if applicable)*	

Approved: _____
John J. Aulbach II, PE, Director
Office of Drinking Water
for the State Health Commissioner pursuant to VA Code §2.2-604

Date: _____

SPECIAL UV PERMIT REQUIREMENTS – STANDARD OPERATION PERMIT

SPECIAL PERMIT REQUIREMENTS

Waterworks Name
PWSID No. ######

These Permit Requirements are issued by the State Board of Health of the Commonwealth of Virginia under authority granted by Title 32.1 of the *Code of Virginia.* Failure to comply with these Requirements shall constitute a violation of the Permit.

UV REACTOR PARAMETER	MINIMUM REACTOR OPERATIONAL LIMIT (ALARM REQUIRED)
UV Intensity *(those using single UV Intensity setpoint control)*	_____W/m^2
UV Dose *(those using calculated dose control)*	_____mJ/cm^2

UV REACTOR PARAMETER	ALARM CRITERIA
High Flow Rate	gpm
Low UV Transmittance *(those using calculated dose control)*	% UVT
Lamp/Ballast Failure	
High Temperature	^0C
Mechanical Wiper Failure *(if applicable)*	

Approved: _____
John J. Aulbach II, PE, Director
Office of Drinking Water
for the State Health Commissioner pursuant to VA Code §2.2-604

Date: _____