

The Final UV Disinfection Guidance Manual: Operations and Maintenance Summary

James Collins,¹ Laurel Passantino, P.E.,² Christine Cotton, P.E.¹

1. Malcolm Pirnie, Tucson, AZ
2. Malcolm Pirnie, Phoenix, AZ

*Corresponding author, 1 S. Church Ave., Suite 1120, Tucson, AZ 85701 Email: jcollins@pirnie.com

ABSTRACT

The number of public water systems (PWSs) implementing ultraviolet (UV) disinfection is increasing due to recent regulations promulgated by the United States Environmental Protection Agency (USEPA). UV disinfection fundamentally differs from the chemical disinfectants traditionally used in drinking water treatment, which makes UV disinfection attractive to meet microbial requirements without creating regulated disinfection byproducts. However, these differences between chemical disinfectants and UV disinfection necessitate operations and maintenance tasks that are different from the activities traditionally performed by water treatment operators. As such, many PWS operators are unfamiliar with the types of tasks needed to keep UV facilities functioning in compliance with the regulatory requirements. The USEPA recognized the need to provide technical information related to all aspects of UV disinfection, including operations and maintenance tasks, and supported the development of the UV Disinfection Guidance Manual (UVDGM). This article summarizes the requirements and recommendations for UV facility operations, maintenance, monitoring, recording, and reporting that are described in detail in Chapter 6 of the UVDGM (USEPA, 2006).

INTRODUCTION

The use of UV light for the disinfection of drinking water is increasing in part because of regulations promulgated by the United States Environmental Protection Agency (USEPA) in January 2006. Public water systems (PWSs) with occurrences of *Cryptosporidium* in their source water may be particularly interested in implementing UV disinfection as an affordable and effective treatment technique for compliance with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Although UV disinfection has been prevalent in Europe for many decades, the use of UV disinfection in North America is relatively new. As such, USEPA recognized the need to provide technical information on the design, validation, and operation of UV facilities and facilitated the development of the UV Disinfection Guidance Manual (UVDGM) to assist PWSs, consulting engineers, and regulatory agencies.

One of the fundamental differences between chemical disinfectants and UV disinfection is UV disinfection doses can not be directly measured to monitor performance. As the dose delivery and monitoring procedures for UV disinfection are significantly different from the procedures familiar to operators of PWSs, it was essential to develop guidance for operators to properly monitor and maintain UV disinfection facilities. This article summarizes the

requirements and recommendations for facility operations, maintenance, monitoring, recording, and reporting that are needed on a continuous, daily, weekly, monthly, and annual basis. More details on the tasks outlined in this article are provided in Chapter 6 of the UVDGM (USEPA, 2006).

OPERATIONAL REQUIREMENTS

An important distinction to make in this article and in the UVDGM is the difference between activities that are *required* versus activities that are *recommended*, as described below.

- **Requirements** are tasks and activities that are required by the LT2ESWTR in order to receive disinfection credit for the UV facility.
- **Recommendations** are tasks and activities that are included in the UVDGM as suggestions for improving operation and monitoring of UV facilities. Recommendations are not required by the LT2ESWTR but may be adopted as requirements by individual states.

According to the LT2ESWTR, a UV facility is required to operate within the validated limits to receive inactivation credit. A reactor is operating outside of the validated limits if any of the following conditions occur:

- Flow rate is greater than the highest validated flow rate;
- UV transmittance (UVT) is lower than the lowest validated UVT;
- UV intensity or calculated dose is lower than the required intensity or dose necessary for the target log inactivation;
- The number of energized lamps is different from the validated number;
- The UV intensity sensor is not calibrated (see monitoring section); and
- The UVT analyzer (if used for UV dose calculation) is not calibrated (see monitoring section).

If a UV reactor is operating outside of the validated limits, it is considered to be operating off-specification. The LT2ESWTR requires 95 percent of the water delivered to

the public each month to be within validated limits (i.e., on-specification). The 95 percent value is calculated using the total volume of water treated each month and the volume of off-specification water produced. The off-specification calculation is based on the entire facility and not individual reactors.

MAINTENANCE OF UV REACTORS

There are no specific regulatory requirements for maintaining UV reactors; however, proper maintenance can reduce the potential for operating outside the validated limits and, therefore, reduce the potential for producing off-specification water. The recommended maintenance tasks are summarized in Table 1. The maintenance tasks and the frequency of performing them can be specific to the UV reactor installed. As such, the UV manufacturer should be consulted when determining the maintenance schedule. See section 6.3 of the UVDGM for detailed descriptions of the recommended maintenance tasks.

Table 1. Recommended Maintenance Tasks (Adapted from Table 6.4 of the UVDGM)

General Task	Frequency
Check cleaning efficiency	Monthly (no cleaning or OCC) Semi-annually (OMC or OMCC)
Check reactor housing, sleeves, and wiper seals for leaks	Monthly
Check intensity of UV lamps and lamp output variability	Bimonthly (MP lamps) Quarterly (LP and LPHO lamps)
Check cleaning fluid reservoir (if provided)	Semi-annually (OMCC)
Calibrate reference UV sensor	Annually
Test-trip Ground Fault Interrupter	Annually
Replace or recalibrate duty UV sensors	When duty UV sensors fail calibration
Check thermometer and/or water level indicator	Manufacturer's recommended frequency
Replace lamp	Lamp/ manufacturer specific
Replace sleeve	Sleeve/ Manufacturer specific
Clean UVT analyzer and replace parts	Manufacturer's recommended frequency
Inspect OMC or OMCC drive mechanism	Manufacturer's recommended frequency
Inspect ballast cooling fan	Manufacturer's recommended frequency

OMC = on-line mechanical cleaning;
OMCC = on-line mechanical chemical cleaning; and
OCC = off-line chemical cleaning.

MONITORING PARAMETERS

To ensure that the UV reactors are operating within the validated limits, the LT2ESWTR requires that select parameters be monitored. PWSs must at a minimum monitor UV intensity, flow rate, and lamp status. States may require additional monitoring. In addition to monitoring the selected parameters, it is also required for a PWS to monitor the calibration of the UV sensors and UVT analyzers (if used to calculate UV dose).

MONITORING UV SENSOR CALIBRATION

USEPA recommends verifying the calibration of duty UV sensors against a reference UV sensor on a monthly basis. Reference sensors are off-line UV sensors that should be at least as accurate as the duty UV sensors and should be constructed identically to the duty UV sensors (except for any modifications to make the reference UV sensor more accurate).

At a minimum, UV sensors in all UV reactors in use (i.e., duty reactors) should be monitored. Monitoring of UV sensors in any stand-by reactors is beneficial because the UV reactor will be operating off-specification if any UV sensors are not in calibration when the reactor is turned on. Verifying the calibration of all duty and stand-by UV reactors allows for all reactors to be ready for use, which provides better operational flexibility.

A duty UV sensor is considered to be in calibration if it reads less than 20 percent higher than the reference sensor (Equation 1).

$$[1] \left(\frac{S_{\text{Duty}}}{S_{\text{Ref}}} \right) \leq 1.2$$

where:

S_{Duty} =
Intensity measured with the duty UV sensor (mW/cm²)

S_{Ref} =
Intensity measured with the reference UV sensor (mW/cm²)

Note that Equation 1 does not include an absolute value. This allows a UV facility to continue operating if the duty UV sensor reading is more than 20 percent lower than the reference sensor. However, this will result in inefficient operation of the UV reactor because more power will be needed to meet the required UV dose or UV intensity than if a calibrated UV sensor was used.

If the calibration ratio is greater than 1.2, one of the following corrective actions should be taken to avoid the reactor being off specification:

- Replace the failed UV sensor with a spare UV sensor;
- Apply a UV sensor Correction Factor (CF) to the affected UV reactor.

A detailed description of how to calculate a CF is in section 6.4.1.1 of the UVDGM. The CF is applied to the required UV intensity or required UV dose. This corrective action is not energy efficient, but it will allow the facility to continue operation until the failed UV sensor(s) can be replaced.

MONITORING UVT ANALYZER CALIBRATION

Monitoring the UVT analyzer calibration is only required when UVT is used to calculate the UV dose during operation (e.g., Calculated Dose Approach). The calibration of an on-line UVT analyzer is evaluated by comparing the reading of the on-line UVT analyzer to that of a calibrated bench-top spectrophotometer using Equation 2.

$$[2] \left| \text{UVT}_{\text{on-line}} (\%) - \text{UVT}_{\text{bench}} (\%) \right| \leq 2 \text{ percent UVT}$$

In this equation, it is important to use the absolute value in the calculations because inaccuracies in the dose calculation can result from both conservative and non-conservative errors in UVT measurements.

The USEPA recommends that on-line UVT analyzers be monitored at least weekly. The monitoring frequency should be adjusted based on the calibration results obtained over the first year of operation and approved by the state. The UVT analyzer can be calibrated on-site using the UV manufacturer's recommended approach if it fails the criterion in Equation 2. If the UVT analyzer fails calibration in four consecutive weeks, USEPA recommends that the UVT analyzer be monitored on a daily basis. If the UVT analyzer can not maintain calibration for 24 hours, the PWS should consider one of the following options to minimize the production of off-specification water:

- Enter manual UVT measurements into the reactor's programmable logic controller (PLC) every four hours and use this measurement in the monitoring strategy;
- Enter the design UVT value into the PLC and verify daily using a bench-top spectrophotometer that the UVT of the water is less than the design UVT.

These options are not intended for long-term use and should not be used for longer than six months.



UV Sensor Check Being Performed on a Medium Pressure UV Reactor

OFF-SPECIFICATION EVENTS

PWSs are required to monitor for off-specification events to calculate the volume of off-specification water produced. The following events trigger off-specification operation:

- Reactor is operating outside of validated limits (e.g., flow rate, UVT, UV intensity, UV dose, number of lamps energized);
- UV sensor is out of calibration and it is not replaced or a CF is not applied;
- UVT analyzer is out of calibration (if required for dose-monitoring strategy) and it is not recalibrated or remedial actions are not taken; and
- UV equipment is not the same or better than the equipment used in validation testing.

Three methods are available for calculating the off-specification volume produced:

- A flow totalizer that automatically records off-specification events can be used;
- The PLC can calculate the volume based on the flow rate in one-minute or less intervals during the off-specification event; and
- The PLC can calculate the volume based on the maximum flow rate during the off-specification event if this method is approved by the state.

These off-specification volumes are divided by the total volume treated to determine the percent off-specification volume produced, which cannot exceed 5 percent.

MONITORING AND RECORDING FREQUENCIES

The LT2ESWTR requires that certain parameters be monitored, but it does not specify the frequency for monitoring. USEPA has recommended that the validated parameters (e.g., flow rate, UV intensity, validated dose (if applicable), and lamp status) be monitored at least every 5 minutes, which is considered to be continuously. These parameters are monitored continuously to ensure the reactors are operating within specification, but the measurements only need to be recorded every 4 hours. Recommended monitoring and recording frequencies for required and recommended monitoring parameters are shown in Table 2 and Table 3, respectively.

Off-specification alarms should be recorded at a minimum of 5 minute intervals. The off-specification alarm should start as soon as the first off-specification condition is monitored and should continue until the reactor returns to within validated limits. It should be noted that the off-specification event may start before it is first monitored and may end before the reactor is monitored as being on-specification. USEPA assumed that the underestimation and overestimation of off-specification water will off-set over time, thereby minimizing any errors in the calculation of off-specification volume. If the monitoring frequency increases, the accuracy of the off-specification calculation also increases.

Table 2. Recommended Monitoring and Recording Frequency for Required Monitoring Parameters (Adapted from Table 6.7 of the UVDGM)

Required Parameter to be Monitored	Monitoring Frequency	Recording Frequency
Off-specification Alarm	Continuous	Minimum of every 5 minutes until the reactor is on-specification
UV Intensity	Continuous	Every 4 hours
UVT*	Continuous	Every 4 hours
Validated Dose*	Continuous	Every 4 hours
Lamp Status	Continuous	Every 4 hours
Flow Rate	Continuous	Every 4 hours
Production Volume	Continuous	Off-specification events and monthly total
Calibration of UV Sensors	Monthly	Monthly
Calibration of On-line UVT Analyzer*	Weekly	Weekly†

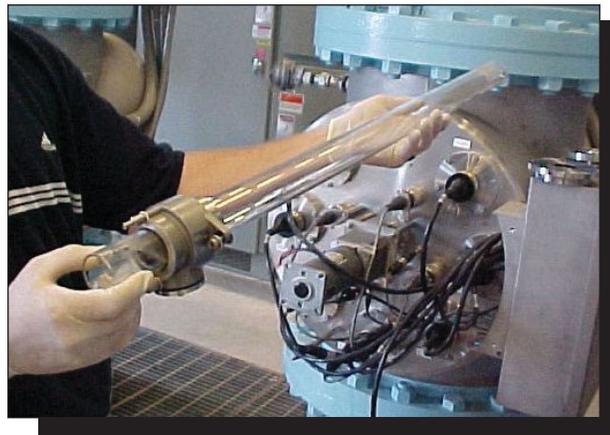
* Required only if necessary for the dose-monitoring strategy (i.e., the Calculated Dose Approach).

† Frequency could be reduced depending on monitoring results

REPORTING REQUIREMENTS

PWSs must prepare and submit monthly reports to the state that detail the percentage of off-specification water produced, the percentage of UV sensors checked for calibration, and the daily low validated dose or low UV intensity. The state may also have additional reporting requirements. Example reporting forms that may be adopted by individual states are included in Section 6.5.2 of the UVDGM.

Table 3. Recommended Monitoring and Recording Frequency for Recommended Monitoring Parameters (adapted from Table 6.8 of the UVDGM)



Visual Inspection of Cleaning Efficiency of UV Lamp Sleeve

Parameter	Monitoring Frequency	Recording Frequency
Power Draw	Continuous	Every 4 hours
Water Temperature (Only for MP Reactors)	Continuous	Daily
UV Lamp On/Off Cycles	Continuous	Weekly (Total cycles per week)
Turbidity (In Addition to Monitoring Otherwise Required Under Subpart H)	Daily	Weekly
pH, Iron, Calcium, Alkalinity Hardness, Oxygen Reduction Potential	Weekly (reduce if fouling is not prevalent)	Weekly
UVT Analyzer Calibration (if not required for dose-monitoring strategy)	Weekly (reduce if appropriate based on operational experience)	Weekly
Operational Age of the Following Equipment: <ul style="list-style-type: none"> • Lamp • Ballast • Sleeve • UV Sensor 	Monthly	Monthly
Calibration of Flow Meter	Monthly	Monthly

SUMMARY

The final UVDGM describes in detail the required and recommended operations, maintenance, monitoring, recording, and reporting necessary to receive inactivation credit with UV disinfection. Included in these recommendations are options if a UV sensor or UVT analyzer fails the recommended criteria, which provide operational flexibility to allow a UV facility to keep operating for a limited time even if the UV sensor or UVT analyzer do not meet criteria.

DISCLAIMER

The information provided in this article is only an overview of the types of operation, maintenance, monitoring, recording, and reporting activities that should be completed for UV facilities. The article is not intended to be a comprehensive discussion of the operations and maintenance requirements and recommendations. For a more thorough presentation of the requirements and recommendations, including step-by-step procedures for completing the tasks and activities, please refer to Chapter 6 of the UVDGM (USEPA, 2006).

REFERENCES

USEPA. 2006. Ultraviolet Disinfection Guidance Manual. U.S. Environmental Protection Agency, Office of Water, Washington DC. http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf