Basis for Acceptance of NSF/ANSI Standard 55 Class "A" Ultraviolet Disinfection Equipment

for

Use in Small Public Water Systems in Colorado

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1. EXECUTIVE SUMMARY

The US EPA's 2006 Ultraviolet Disinfection Guidance Manual (UVDGM) provides guidance for public water systems (PWS) employing ultraviolet disinfection in meeting the requirements of both the Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules (LT1/LT2ESWTR). LT1/LT2ESWTR stipulates a minimum treatment of key pathogens coupled with a tiered level of required inactivation for *Cryptosporidium* based on the raw water concentration. In Colorado, the majority of PWS's that are classified as surface water (SW) or groundwater-under-the-direct-influence (GWUDI) of surface water, subject to the LT1/LT2ESWTR, are required to treat water to the following levels:

- 4-log removal/inactivation of viruses
- 3-log removal/inactivation of *Giardia*
- 2-log removal of *Cryptosporidium*

The UVDGM provides detailed requirements for validation testing for UV equipment for use in PWS water treatment installations. The validation process is rigorous and necessarily involves the testing of varying UV intensities, flow rates, and water quality conditions. The UVDGM however does allow for the States to consider alternative validation protocols (refer to Section 5.2.2 of the UVDGM). The UVDGM indicates that UV systems certified under NSF Standard 55 should be evaluated on a case-by-case basis. The certification process defined by NSF Standard 55 Class A is not equivalent to the validation requirements of the UVDGM and the State of Colorado does not recognize them as equal. However, this paper provides the basis for rationale and limitations that the State of Colorado employs in approving the use of NSF Standard 55 Class A ultraviolet disinfection equipment.

There are numerous small PWS's in Colorado that often lack the resources and level of sophistication that larger PWS's have available. For the purpose of this paper, a "small" PWS is defined as having an individual treatment plant capacity of less than 100 gallons per minute (gpm). These systems typically do not have full-time on-site water treatment operators. These systems typically have a fixed flow rate treatment capacity best described in gallons-per-minute (gpm) rather than million-gallons-per-day (MGD). The water source(s) for the small PWS are typically fixed flow rate wells, springs, or infiltration galleries, often classified as GWUDI. These small PWS's can benefit from the use of the low cost, widely available NSF Standard 55 Class A UV (NSF55A) equipment. The State of Colorado finds that under certain limited circumstances, NSF55A equipment can provide treatment efficacy equivalent to that required by the UVDGM. The circumstances under which the State of Colorado may approve NSF55A UV equipment are described in Table 1.

Table 1 - System Requirements for NSF55A Eligibility in Colorado

Parameter		Value or Description
UV equipment Certification		NSF/ANSI Standard 55 Class A only
Flow through UV reactor		Less than or equal to NSF55A certified capacity for reactor
Treatment Plant Capacity		100 gallons per minute (maximum)
UV Influent Water Quality		Iron, manganese, hardness, UVT, turbidity, etc. all less than or equal to manufacturer's requirements.
Minimum NSF55A certified UV dose		40 mJ/cm^2
Maximum Department approved log inactivation credit for:	*Giardia*	0.5-log
	Cryptosporidium	Zero. No inactivation credit for UV treatment will be given.
	virus	Zero. No viral inactivation credit for UV treatment will be given.
Dose Monitoring Approach		UV Intensity Setpoint
Other Treatment Requirements		UV equipment must be preceded by a Department approved filtration technology providing 2.5-log *Giardia* removal / 2.0 log *Cryptosporidium* removal credit and followed by a Department approved chemical disinfection system providing 4-log virus inactivation.

2. INTRODUCTION

This paper presents the Water Quality Control Division's (Department) comparison of the requirements of US EPA's 2006 *Ultraviolet Disinfection Guidance Manual* (UVDGM) and the criteria of the 2012 *NSF/ANSI Standard 55 Ultraviolet Microbiological Water Treatment Systems*. The NSF/ANSI Standard 55 has criteria for two classes of UV equipment: Class A and Class B. Class A is rated to provide an ultraviolet (UV) dose of 40 mJ/cm^2 and is specifically designed to "inactivate …microorganisms, including bacteria, viruses, *Cryptosporidium* oocysts, and *Giardia* cysts from contaminated water" (NSF/ANSI 55 section 1.2.1). Class B equipment is certified to provide a UV dose of 16 mJ/cm^2 and is designed for "supplemental bactericidal treatment of disinfected public drinking water" (NSF/ANSI 55 Section 1.2.2). Class B reactors are designed for the purpose of adding additional treatment to water already considered potable water and fully compliant with the Colorado Primary Drinking Water Regulations (CPDWR). The purpose of this document is to allow certain UV reactors for disinfection of a non-potable source water, hence, Class B was not considered. However, the Department does find that the use of NSF/ANSI 55 Class A (NSF55A) UV equipment may be suitable and approved for use by public water systems (PWS) under certain limited conditions.

A key distinction between the UVDGM and NSF55A is that NSF55A quantifies a fixed, numeric minimum UV dose for equipment certification whereas the UVGDM requires UV disinfection to be validated for the appropriate, site specific inactivation credit objective. NSF55A UV equipment is certified to provide a minimum UV dose of 40 mJ/cm^2 within specified operating conditions. The UVDGM validation procedure allows for the PWS and/or UV manufacturer to designate the validated UV dose. The NSF certification conditions are not the same as the UV validation requirements outlined in the UVDGM, and NSF55A certification, by itself, cannot be considered equivalent to the validation process to that outlined by the UVDGM. However, there are possible instances where use of NSF55A equipment can meet the requirements of the UVDGM and be suitable for use in meeting the disinfection requirements of both the Long Term 1 Enhanced Surface Water Treatment Rule and the Long Term 2 Enhanced Surface Water Treatment Rule (LT1/LT2ESWTR).

The UVDGM requires that UV equipment be validated for the intended operation conditions by the manufacturer and routinely in the field. The validation requirements of the UVDGM are rigorous, and therefore, operator intensive and costly. Manufacturers of UV equipment do not typically go to the expense of validation for low-cost equipment suitable for flows in the tens of gallon per minute range. As a practical result, there are few, if any, UV options for small systems that have been validated in accordance with the UVDGM. Table 2 below contains a summary of the UVDGM validation requirements.

Table 2 - Summary of UV Validation Requirements per the EPA UVDGM

Requirement	Conditions	Citation
Validated operating conditions must include	• Flow rate • UV intensity as measured by a UV sensor • UV lamp status	40 CFR 141.720 (d)(2)
Validation testing must include	• Full-scale testing of a reactor that conforms uniformly to the UV reactors used by the water system • Inactivation of a test microorganism whose dose-response characteristics have been quantified with a low-pressure mercury vapor lamp	40 CFR 141.720 (d)(2)(ii)
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 in the reactor • Failure of UV lamps or other critical components • Inlet and outlet piping or channel configurations of the UV reactor	40 CFR 141.720 (d)(2)(i)

Source: UVDGM Table 5.1 Summary of LT2ESWTR Validation Requirements

For any given UV installation, the UVDGM requires that the particular model of UV reactor be validated for the intended inactivation credit objective under the operating conditions it will be used. Specifically, the unit will be validated to provide a particular UV dose (measured in mJ/cm^2) under the specified operating conditions (flow rate, water quality, etc.) Depending upon the level of total treatment complexity (i.e., filtration, water type, etc.) and the LT1/LT2ESWTR removal/inactivation requirements, the necessary level of UV dose can vary and be site specific. A system could meet the LT1/LT2ESWTR requirements using a combination of filtration, UV disinfection and chemical disinfection.

Therefore, the level of UV dose required will depend upon the various treatment processes employed by the PWS and level of pathogen removal stipulated by the LT1/LT2ESWTR. The PWS will design and employ UV treatment processes to deliver the site specific UV dose in conjunction with other treatment processes to provide a cumulative effective pathogen destruction/removal rate. According to the UVDGM, the log inactivation of pathogens varies with the level of UV dose as shown in Table 3. Note that these UV dosages apply to post-filtration applications.

Table 3 – UV Dose Requirements (mJ/cm^2) for Pathogen Inactivation

Target Pathogen	Log Inactivation							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

Source: UVDGM Table 1.4 UV Dose Requirements – millijoules per centimeter squared (mJ/cm^2)

For example, if a particular PWS is using a form of filtration that provides 2.0-log *Cryptosporidium* removal and must provide a total *Cryptosporidium* treatment of 5.0-log, then the use of UV to supply the remaining 3.0-log inactivation of *Cryptosporidium* may be employed. For this example case, according to Table 3 above, the UV treatment system must be validated for 12 mJ/cm^2 under all operating conditions. The design of the UV equipment chosen for this example use can be optimized to provide only the UV dose required (i.e., 12 mJ/cm^2).

The UVDGM provides the protocol for validating UV equipment under a wide variety of operating conditions and effective UV dosages. In contrast, NSF55A does not provide flexibility in UV dosages. NSF55A is strictly limited to a UV dose of 40 mJ/cm^2 under the manufacturer specified operating conditions. Note that a large water treatment facility would probably choose to target their UV equipment design to provide the optimal UV dose and save on electrical and maintenance costs. For larger installations, the cost savings of targeting the equipment size more than offsets the cost and effort of undergoing validation testing per the UVDGM. The Tojan UVMax Pro 50UV, one of the smallest validated UV reactors, has a minimum hydraulic capacity of 50 gpm at a manufacturer's recommended cost of greater than $5,000. Other small validated reactors (12" diameter) begin at as much as $50,000 for a full installation (i.e. Trojan, 4L12 reactor). Alternately, NSF55A UV equipment is available from a number of manufacturers at certified flow rates ranging from 10 to 30 gallons per minute (gpm). Costs for NSF55A UV equipment ranges from $1,500 for a 10-gpm unit to $2,200 for a 30-gpm unit (Source: USABluebook for Trojan UVMax Pro).

The UVDGM does allow for the States to consider alternative validation protocols. Section 5.2.2 of the UVDGM indicates that UV equipment bearing NSF Standard 55 certification should be evaluated on a "case-by-case basis". This paper discusses the State of Colorado's evaluation of NSF Standard 55 Class A equipment for use by PWS's under limited circumstances. The Department provided this evaluation by comparing the capabilities of the NSF55A UV unit against the UVDGM requirements and establishing operational and monitoring parameters to be used in combination with a maximum treatment credit that minimizes risk.

3. DOSE MONITORING STRATEGIES

According to the UVDGM, UV equipment employed by a PWS must operate under one of two approved dose monitoring strategies. The UVDGM allows for PWS to use UV equipment in either a "UV Intensity Setpoint" approach or a "Calculated Dose" approach.

UV INTENSITY SETPOINT APPROACH

This approach relies on one or more "setpoints" for UV intensity that are established during validation testing to determine UV dose. The UV intensity measured by the UV sensors must meet or exceed the setpoint(s) to ensure delivery of the required dose. Reactors must also be operated within validated operation conditions (flow rate, lamp status, etc.) In the UV Intensity Setpoint Approach, the ultra-violet transmittance (UVT) of the water does not need to be monitored separately. Instead, the intensity readings by the sensors account for changes in UVT. The operating strategy can be with either a single setpoint (one UV intensity setpoint is used for all validated flow rates) or a variable setpoint (UV intensity setpoint varies for a range of validated flow rates).

CALCULATED DOSE APPROACH

This approach uses a dose monitoring equation to estimate the UV dose based on the flow rate, UV intensity, and UVT, as measured during reactor operations. During reactor operations, the UV reactor control system inputs the measured parameters into the dose monitoring equation to produce a calculated dose. The calculated dose (based on real-time operating conditions such as flow rate, UV intensity, UVT, etc.) is compared to the required dose for the target pathogen and log inactivation level.

The Calculated Dose Approach appears to be appropriate for treatment systems with varying flow rates and varying water quality. Under optimal conditions (low flow and high quality) a reduction in UV energy can be utilized to provide the required UV dose. As water treatment conditions deteriorate (higher flow and lower quality) additional UV energy can be utilized (i.e., powering on additional units or lamps) to provide the required dose. The Calculated Dose approach requires a level of sophistication, instrumentation, controls and operation that are typically not available to a small PWS. The UV Intensity Setpoint Approach appears to be optimal for a PWS which has relatively constant raw water quality and treatment flow rates. For a small PWS, the State of Colorado finds that only the single Intensity Setpoint approach is applicable for utilizing NSF55A UV equipment to comply with the log inactivation requirements of Article 7 of the Colorado Primary Drinking Water Regulations (CPDWR) due to the equipment limitations, the validation requirements, and associated costs to satisfy the calculated dose approach.

4. UVDGM VALIDATION AND NSF/ANSI STANDARD 55A CERTIFICATION

The UVDGM validation procedure allows for the PWS and/or the UV reactor's manufacturer to designate the validated dose of UV irradiation delivered. This procedure is advantageous because it allows for PWS and/or manufacturers to size UV reactors for the site specific UV dose required. In contrast to this approach, NSF55A stipulates that the UV equipment must deliver a minimum dose of 40 mJ/cm^2 "at the alarm set point". The NSF55A equipment must deliver a dose of 40 mJ/cm^2 regardless of water quality conditions and irrespective of any particular inactivation credit objective.

SIMILARITIES BETWEEN UVDGM AND NSF55A

- Both NSF55A and the UVDGM allow for the PWS/UV manufacturer to specify the operating conditions (i.e., flow rate, water quality, etc.).
- Both NSF55A and the UVDGM require a dose/response relationship to be developed for the challenge microorganism using collimated UV light.
- Both NSF55A and the UVDGM allow for use of MS2 Phage as an appropriate indicator organism
- Both NSF55A and the UVDGM establish UV reactor dosages by comparing the apparent log-reduction of challenge microorganism through the reactor against the previously established dose/response relationship.. The UVDGM describes this relationship through the Reduction Equivalent Dose (RED) parameter using the field-measured log inactivation as the input variable.

DIFFERENCES BETWEEN UVDGM AND NSF55A

- UVDGM requires that both lamp fouling and lamp aging be accounted for during validation testing. The "validated dose" must be confirmed to be delivered under aged and fouled lamp conditions. Note that the validated dose is not specified by UVDGM, rather it is to be established by the PWS or UV reactor's manufacturer as that which meets the appropriate inactivation credit objective.

  In contrast, NSF55A does not specifically address aged or fouled lamps for Class A systems. Rather the units are to be equipped with a UV sensor which is to alarm and/or disable the unit when the UV dose falls below 40 mJ/cm^2. The NSF55A procedure requires that the sensor alarm be tested by delivering a dose of parahydroxybenzoic acid (PHBA) into the feed stream sufficient to activate the alarm system. Sufficient PHBA shall be added to reduce UV light transmission to the alarm set point in the device. Appendix D of the UVDGM indicates that PHBA is an acceptable UV-absorbing chemical which can be added to the bulk flow of water to simulate high UV absorbance. NSF55A relies on the alarm sensor to confirm the dose (40 mJ/cm^2) regardless of the means of reduced UV efficacy (fouling, aging, water quality, etc.).
- UVDGM requires that the "validated dose" contain a reduction factor thtat accounts for "biases associated with using a challenge microorganism instead of a target pathogen and for experimental uncertainty" (UVDGM 5.2.1). NSF55A does not have any similar reduction factors.

These highlights only briefly discuss the similarities and differences between UVDGM and NSF55A, Table 5.1 of the UVDGM provides a summary of LT2ESWTR UV validation requirements. These requirements are listed in Table 4 on the following page in comparison to the provisions of NSF55A. Most of the requirements of UVDGM can be met by NSF55 with the exception of addressing the

uncertainty associated with UV sensor measurements. This exception, in conjunction with not providing for "reduction factors" due to experimental uncertainty, is the basis for the Department not accepting the NSF55A 40 mJ/cm^2 dose rating as a UVDGM validated dose. However, the Department finds that a reduction of the NSF55A certified dose is appropriate for approval of NSF55A equipment being used in PWS treatment systems. Consideration of an appropriate reduction factor is discussed in greater detail in the following section of this paper.

Table 4 – NSF55A Comparison UVDGM Validation Requirements

Conditions required to be accounted for by UVDGM	NSF55A Comparison Note	NSF55 Reference
Flow rate	Flow rate is specified by manufacturer. The maximum possible flow rate through the reactor shall be the test flow.	7.2.2.7.a)
UV intensity as measured by a UV sensor	UV intensity is "measured" by a sensor, however; the standard does not specify reporting of the value. The standard does specify that when the intensity falls below the threshold of providing a dose of 40 mJ/cm^2 the reactor must go into alarm mode	7.2.2.1 7.2.2.8.2.1
UV lamp status	Not addressed by NSF55A. The assumption is that if there is a lamp status issue (i.e., lamp not operating) the reactor will go into alarm mode if the UV intensity does not deliver the dose of 40 mJ/cm^2	6.2.1
Full-scale testing of a reactor that conforms uniformly to the UV reactors used by the water system	Reactor make, model and class designation are reported in the certification.	8.1.1
Inactivation of a test microorganism whose dose-response characteristics have been quantified with a low-pressure mercury vapor lamp	The test microorganism for NSF/ANSI Standard 55 Class A systems is MS-2 Coliphage American Type Culture Collection (ATCC)14 # 15597-B1. This is the only test microorganism allowed under NSF55. This organism is also recognized by the UVDGM and Appendix A includes information regarding stock preparation and published dose-response curves	7.2.1.1
UV absorbance of the water	UV absorbance of bulk water is not directly accounted for under NSF55A. However, it is "indirectly" accounted for as it is one of several variables that can reduce the amount of UV light striking the alarm sensor. Thus any amount of UV_{ABS} that sufficiently reduces the dose to below 40 mJ/cm^2 would be accounted for. - Additionally, NSF55A requires that PHBA be added to the feed stream to increase UV_{ABS} and activate the alarm. The disinfection test procedure shall be conducted at the alarm condition (i.e., enough UV_{ABS} to activate alarm) to verify a dose of 40 mJ/cm^2.	7.2.2.1 6.2.3.3.d) 7.2.2.5.1 7.2.2.7.d)
Lamp fouling and aging	Lamp fouling and aging are not directly accounted for under NSF55A. However, it is "indirectly" accounted for as it is one of several variables that can reduce the amount of UV light striking the alarm sensor. Thus any reduction in UV irradiance that sufficiently reduces the dose to below 40 mJ/cm^2 would be accounted for.	7.2.2.1
Measurement uncertainty of on-line sensors	NSF/ANSI Standard does not address uncertainty of on-line sensors	NONE
UV dose distributions arising from the velocity profiles through the reactor	NSF/ANSI Standard does not address UV dose distributions arising from velocity profiles through reactor. However, the reactor is tested at the maximum flow rate (corresponds to highest velocity and shortest residence time) and must deliver a dose of 40 mJ/cm^2	For max flow refer to 6.2.3.3.a)
Failure of UV lamps or other critical components	Not addressed by NSF55A. The assumption is that if there is a lamp status issue (i.e., lamp not operating) the reactor will go into alarm mode if the UV intensity does not deliver the dose of 40 mJ/cm^2	6.2.1
Inlet and outlet piping or channel configurations of the UV reactor	Not directly addressed in the NSF55 test procedure. However, the UV reactor's manufacturer must specify the plumbing connections for the test procedure and include them in the detailed instructions for installation, operation and maintenance for each system.	8.1.1

Compare to: UVDGM Table 5.1 Summary of LT2ESWTR Validation Requirements

5. DEPARTMENT'S METHOD TO RATE NSF55A EQUIPMENT

In Colorado, the majority of PWS's classified as surface water (SW) or groundwater-under-the-direct-influence (GWUDI) of surface water, subject to LT1/LT2ESWTR, are required to treat water to the following levels per Article 7 of Colorado Primary Drinking Water Regulations (CPDWR):

- 4-log removal/inactivation of viruses
- 3-log removal/inactivation of *Giardia*
- 2-log removal of *Cryptosporidium*

Note that there are a few PWS's in Colorado with more stringent removal criteria based on the raw water concentration of *Cryptosporidium*.

To meet the required minimum log inactivation credits, Article 7 of the CPDWR requires that surface water and groundwater under the direct influence of surface water sources receive treatment through approved filtration and disinfection processes. While Article 7 of the CPDWR includes some typical examples of approved filtration technologies that can be used, small systems, in general, do not use the CPDWR listed technologies due to economic and operational infeasibilities. To help accommodate the needs of small water systems, the Department has pre-accepted a number of alternative filtration technologies that meet the requirements of Article 7 of the CPDWR. Since filtration methods do not meet all the removal/inactivation requirements by themselves, additional treatment methods, such as UV disinfection and chlorination, are used in combination with the filtration. The Department considered whether the NSF55A UV reactors can reliably achieve the required treatment credits for viruses and *Giardia* not provided by the filtration treatment and for enhanced treatment of *Cryptosporidium* based on source water needs.

The majority of the filtration technologies which are economically feasible for small systems are bag or cartridge filtration systems. Bag or cartridge filtration, when accepted by the Department, will be granted compliance credit of 2.5-log removal for *Giardia*, 2.0-log removal for *Cryptosporidium*, and no removal for viruses. Thus, the Department considered whether NSF55A certified UV reactor models have the ability to provide the remaining 0.5-log inactivation credit for *Giardia*, 4-log inactivation of viruses, and any log credit removal for *Cryptosporidium*. With the initial understanding that the NSF55A UV reactor models provide a certified dose of 40 mJ/cm^2, the Department first considered what level of pathogen and virus inactivation this dose can theoretically provide. Table 3 indicates that the certified 40 mJ/cm^2 dose from a NSF55A UV reactor can theoretically provide significantly more treatment than the required UV does of 22 mJ/cm^2 to achieve 4.0-log inactivation of *Giardia* and *Cryptosporidium*. Similarly, Table 3 indicates that the certified 40 mJ/cm^2 dose from a NSF55A UV reactor can theoretically provide slightly more treatment than the required UV dose of 39 mJ/cm^2 to achieve 0.5-log inactivation of viruses. While a strong indication that the NSF55A UV reactor can achieve log credit inactivation for pathogens and viruses, the 40 mJ/cm^2 certification does not provide the same level of validation testing and operational monitoring scrutiny as the UVDGM validated dose to ensure continuous inactivation of pathogens and viruses. These shortcomings must be considered when setting inactivation credits.

The Department investigated whether, and under what conditions, NSF55A UV reactors could be expected to provide a specific UV dose for log inactivation with a high level of confidence. Two aspects contribute to this evaluation, treatment and operational monitoring. The NSF55A certification provides a onetime manufacturer's test that does not address all of the aspects of the UVDGM validated dose. The Department investigated if the certified dose could be associated with a specific performance confidence (i.e. operational safety factor) that would allow the Department, when combined with appropriate monitoring, to accept NSF55A UV reactors for specific log credit removals. As a first step, the

Department began by considering appropriate log credit removals for the NSF55A UV reactor through a comparison to the validated dose requirements of the UVDGM.

According to the UVDGM, the "validated" dose of a given reactor is the reduction equivalent dose (RED) reduced by a "Validation Factor" and can be calculated using the following equation:

$$Validated\ Dose = RED/VF$$

Where: RED = Reduction Equivalent Dose
VF = Validation Factor

RED equates a specific UV dose to a corresponding log credit inactivation through laboratory experimentation. VF, the validation factor, accounts for "biases associated with using a challenge microorganism instead of a target pathogen and for experimental uncertainty". The Validation Factor is defined as follows (UVDGM Equation 5.13):

$$VF = B_{RED} \times \left(1 + \frac{U_{VAL}}{100}\right)$$

Where: VF = Validation Factor
B_{RED} = RED Bias Factor
U_{VAL} = Uncertainty of Validation expressed as a percentage

The Uncertainty of Validation (U_{VAL}) is also referred to as the "experimental uncertainty" by the UVDGM. The UVDGM describes three variables which contribute to U_{VAL} for systems using the intensity setpoint approach. These three variables are: the uncertainty in the Setpoint value (U_{SP}), the uncertainty of UV sensor measurements (U_S), and the uncertainty of the UV dose-response inactivation relationship of the target pathogen and test microorganism (U_{DR}). Using the most conservative approach outlined in the decision tree of Figure 5.4 in the UVDGM, U_{VAL} is to be calculated as follows:

$$U_{VAL} = \sqrt{\left({U_{SP}}^2 + {U_S}^2 + {U_{DR}}^2\right)}$$

Where: U_{VAL} = Uncertainty of Validation
U_{SP} = Uncertainty in the UV Setpoint Value
U_S = Uncertainty in the UV sensor measurement
U_{DR} = Uncertainty in the dose-response relationship

A NSF/ANSI Standard 55 certification does not contain enough information to properly evaluate the Uncertainty of Validation or the RED bias factor. So, instead of applying these formulas from experimental data per the UVDGM, the Department chose to take the following approach:

1. Work from the known 40 mJ/cm^2 dose applied by the NSF55A UV reactor and the established Reduction Equivalent Dose (i.e. dose tied to specific pathogen and virus reductions) to determine the associated uncertainty and biases.
2. Determine whether the calculated uncertainty in conjunction with minimum monitoring requirements could provide a high level of confidence that the water treated through NSF55A UV reactors satisfies minimum log credit reductions for pathogens.

To test the above approach, the Department worked through an example calculation for *Giardia* treatment using the following assumptions:

- Per Table No. G.16 of the UVDGM, the Validated Dose must equal 1.5 mJ/cm^2 to achieve 0.5 log *Giardia* inactivation.
- Assuming the worst UVT (%) and Challenge UV Sensitivity (mJ/cm^2/log I) in Table No. G.16 of the UVDGM as a conservative measure, the RED Bias factor equals 6.09.
- Since RED equals the applied dose, the Department used the NSF55A certified 40 mJ/cm^2 as RED.

Working from these assumptions, the Department calculated the uncertainty and bias. The first step to calculate the Validation Factor is as follows:

$$VF = \frac{40\frac{mJ}{cm^2}}{1.5\frac{mj}{cm^2}} = 26.7$$

Using this calculated value, the Department calculated U_{VAL} by using the worst case option for $B_{red}B_{RED}$ as follows:

$$U_{val} = 100 * \left(\frac{26.7\frac{mJ}{cm^2}}{6.09} - 1\right) \sim 338\%$$

The result means that if the combined uncertainty and/or bias from all factors, such as U_S, U_{SP}, and U_{DR}, equals or exceeds 338 percent when treating the worst allowable water quality through the reactor, the NSF55A UV reactor produces water not fully capable of meeting the associated *Giardia* log inactivation. This answer represents a possible scenario that the Department must evaluate when used in conjunction with potential monitoring options. For the full range of options to be considered, the Department followed the methodology used in this example to develop the uncertainty and bias for a range of log credit removals for viruses, *Cryptosporidium*, and *Giardia*. The results of this work are found in Table 5.

Table 5 – Uncertainty of Validation (UVAL) Percentage for Pathogen Inactivation

Target Pathogen	Value	Log Inactivation							
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Giardia	Percent Uncertainty (U_{VAL})	337.9	147.1	78.3	28.6	3.9	N/A	N/A	N/A
	Validated Dose (mJ/cm^2)	1.5	2.1	3.0	5.2	7.7	11	15	22
	B_{red}	6.09	7.71	7.48	5.98	5.00	4.17	3.54	2.73
Cryptosporidium	Percent Uncertainty (U_{VAL})	332.5	130.5	60.0	23.4	0.1	N/A	N/A	N/A
	Validated Dose (mJ/cm^2)	1.6	2.5	3.9	5.8	8.5	12	15	22
	B_{red}	5.78	6.94	6.41	5.59	4.70	3.94	3.54	2.84
Virus	Percent Uncertainty (U_{VAL})	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Validated Dose	39	58	79	100	121	143	163	186
	B_{red}	1.02	1.06	1.07	1.08	1.09	1.09	1.09	1.09

"N/A" designates conditions where the NSF55A UV reactor cannot provide a sufficient dose to meet the log inactivation.

The Uncertainty of Validation is developed from three main variables, U_S, U_{SP}, and U_{DR}. The most conservative relationship between the Uncertainty of Validation and the U_S, U_{SP}, and U_{DR} found in the UVDGM is found above in this section. Each of these variables can represent a different uncertainty value that contributes toward the overall Uncertainty of Validation. By working from the Uncertainty of Validation, the Department evaluated how much one, two, or three of these contributing variables would have to be in error to be equal to or in excess of the Uncertainty of Validation percentages found in Table 5. For this assessment, the Department assumed that multiple variables were of equal uncertainty for simplicity. These results are outlined in Table 6.

Table 6 – Percent Uncertainty Thresholds for US, USP, and UDR

Target Pathogen	Number of Variables in Error	Log Inactivation				
		0.5	1.0	1.5	2.0	2.5
Giardia	One	337.9	147.1	78.3	28.6	3.9
	Two	238.9	104.0	55.33	20.2	2.8
	Three	195.1	84.9	45.18	16.5	2.2
Cryptosporidium	One	332.5	130.5	60.0	23.4	0.1
	Two	235.1	92.3	42.4	16.5	0.1
	Three	192.0	75.4	34.6	13.5	0.1
Virus	One	0.6	N/A	N/A	N/A	N/A
	Two	0.4	N/A	N/A	N/A	N/A
	Three	0.3	N/A	N/A	N/A	N/A

N/A designates conditions where the NSF55A UV reactor cannot provide a sufficient dose to meet the log inactivation.

The values in this table allow the Department to evaluate the potential whether the NSF55A UV reactor will produce off specification water if one or more of the test variables exceed these uncertainties. For example, consider the probability of a single source of error, such as the Uncertainty of the UV Sensor Measurement (U_S), exceeding the percentage listed in Table 6 for a 0.5 log inactivation of viruses. Since the U_S would have to equal or exceed 0.6 percent error, the likelihood of the NSF55A UV reactor creating off specification water appears highly probable. Similarly, consider the probability of all three of the variables contributing toward the overall uncertainty, U_S, U_{SP}, and U_{DR}, equaling or exceeding the percentage listed in Table 6 for a 0.5 log inactivation of viruses. Since the U_S, U_{SP}, and U_{DR} would each have to equal or exceed 0.3 percent error, the likelihood of the NSF55A UV reactor creating off specification water appears highly probable. Alternately, consider the probability of all three of the variables contributing toward the overall uncertainty, U_S, U_{SP}, and U_{DR}, equaling or exceeding the percentage listed in Table 6 for a 0.5 log inactivation of *Giardia*. Since the U_S, U_{SP}, and U_{DR} would each have to equal or exceed 195.1 percent error, the likelihood of the NSF55A UV reactor creating off specification water appears highly improbable.

Based on the three contributing uncertainties, only one uncertainty appears to be capable of fully failing under operating conditions. This factor is the Uncertainty of the UV Sensor Measurement (U_S). A sensor has the potential to provide false high readings that result in error of an unknown magnitude, provide false low readings that result in error of an unknown magnitude, or completely fail. If the required monitoring prevents the treatment of water through the NSF55A UV reactor when the sensor registers a UV dose less than 40 mJ/cm^2, two of the potential failures become inconsequential. For the remaining concern of a false high reading, the Department considered what level of uncertainty posed an unacceptable risk for producing off specification water for viruses, *Giardia*, and *Cryptosporidium*.

Assuming that the Department can optimize the monitoring requirements, discussed in Section 6 of this document, the Department finds the following for defining the log credit treatment capacities of the NSF55A UV reactor for viruses, *Cryptosporidium*, and *Giardia*:

VIRUS INACTIVATION CREDIT FOR NSF55A UV INSTALLATIONS

Referring to the information presented previously in Table 3, a UV dose of 39 mJ/cm^2 is required to deliver a 0.5-log inactivation credit for viruses. A 0.6 percent error of any experimental data element would prevent the NSF55A UV reactor from providing this minimum dose. The high probability of an error that exceeds 0.6 percent presents too much risk to ensure the treatment system will meet the required treatment. **The Department does not award any virus inactivation credit for the NSF55A UV equipment.**

CRYPTOSPORIDIUM INACTIVATION CREDIT FOR NSF55A UV INSTALLATIONS

Item 7.3.1(1) of the CPDWR requires that treatment systems provide 2-log credits of treatment for the removal of *Cryptosporidium*. This requirement is very clear that this treatment must be provided through removal and not inactivation. Based on this portion of the regulation, UV cannot be use for the initial 2-log treatment of *Cryptosporidum*. Per the requirements for enhanced treatment for *Cryptosporidium*, filtered systems with confirmed *Cryptosporidium* in the source water require additional log credit treatment. While UV treatment may be used to achieve this additional *Cryptosporidium* treatment, item 7.4(2) of the CPDWR outlines the requirements of the reactor validation testing and operating conditions; NSF55A UV reactors cannot meet these requirements. Based on these requirements, the Department has determined that only validated UV reactors with more stringent monitoring requirements are appropriate for use in meeting the enhanced treatment removal/inactivation requirements for *Cryptosporidium*. **The Department does not award any *Cryptosporidium* inactivation credit for the NSF55A UV equipment**.

GIARDIA INACTIVATION CREDIT FOR NSF55A UV INSTALLATIONS

Item 7.1.1 of the CPDWR requires the use of filtration to fully or partially achieve 3-log removal/inactivation of *Giardia*. In addition to filtration, UV inactivation is an appropriate tool to treat *Giardia*. The NSF55A UV reactor has the theoretical capability to provide up to 2.5-log inactivation of *Giardia* if operating at the certified capacity (40 mJ/cm^2). While certified, the NSF55A UV reactors are not tested or monitored to account for items such as lamp fouling and aging, measurement uncertainty of on-line sensors, and failure of system components. To account for these variables, the Department can set minimum monitoring requirements and apply appropriate safety factors. The Department investigated the safety factor approach by comparing the NSF55A UV reactor to the UVDGM basis.

While 1.0-log inactivation of *Giardia* might appear to be a reasonable treatment credit, this treatment credit only provides an approximate 150 percent Uncertainty of Validation safety factor, but the NSF55A certification and the approach used by the Department does not account for items such as lamp age. The risk for failure must be minimized further. The Department cannot independently ascertain the risk level associated with unknowns not analyzed, but believes that the NSF55A UV reactor has a low probability of failure when providing 0.5-log inactivation of *Giardia*. **Based on the information presented in Table 5, the Department finds that NSF55A UV reactors can provide 0.5-log inactivation of *Giardia* in combination with the monitoring requirements outlined in section 6 of this document.**

6. DESIGN AND OPERATION REQUIREMENTS

The Department finds that UV disinfection equipment which is certified under NSF/ANSI Standard 55 Class A can be successfully used to comply with the log inactivation requirements of Article 7 of the Colorado Primary Drinking Water Regulations (CPDWR). The technology meets or exceeds the requirements of the *State of Colorado Design Criteria for Potable Water Systems* and is accepted for use as a technology to meet the log inactivation requirements for *Giardia* subject to the conditions outlined below.

INSTALLATION CONDITIONS

The installation conditions under which the Department deems that NSF/ANSI Standard 55 Class A UV disinfection reactors are approvable for use in Colorado for complying with the requirements of Article 7 of the Colorado Primary Drinking Water Regulations (CPDWR) are included in Table 7.

Table 7 – Installation Conditions for NSF/ANSI Standard 55 Class A UV Disinfection Equipment

Condition		Requirement
Treatment Plant Capacity		100 gallons per minute (maximum)
Flow through UV reactor		Less than or equal to NSF55A certified capacity for reactor
Water Treatment Process required upstream of UV equipment		Department approved filtration process providing a minimum 2.5-log *Giardia* removal / 2.0 log *Cryptosporidium* removal
Water Treatment Process required downstream of UV equipment		Department approved chemical disinfection providing a minimum of 4-log virus inactivation credit.
Minimum UV dosage provided as certified by NSF/ANSI Standard 55		40 mJ/cm^2
Maximum Department approved log inactivation credit for:	*Giardia*	0.5-log
	Cryptosporidium	Zero. No inactivation credit shall be granted for *Cryptosporidium*.
	viruses	Zero. No inactivation credit shall be granted for viruses.

TREATMENT CAPACITY LIMITATIONS FOR NSF55A UV INSTALLATIONS

The Department has determined that the use of NSF55A UV equipment shall be limited to treatment facilities with a maximum capacity of 100 gallons per minute (gpm). The primary intent of the Department's acceptance of NSF55A UV equipment is to provide a framework for small PWS's to use readily available, small flow, cost effective UV equipment in complying with log inactivation requirements of Article 7 of the CPDWR. The Department acknowledges that several NSF55A UV reactors may be operated in parallel to provide a larger total treatment capacity greater than the individual unit capacities. However, the Department limits the total capacity of a parallel unit installation to 100 gpm. For treatment plants that require UV disinfection flows greater than 100 gpm the Department finds that NSF55A equipment, and its associated monitoring requirements may be replaced with validated UV reactors for roughly the same cost, but with a higher level of monitoring. For treatment plant capacities above 100 gpm the Department will require that a UV disinfection process comply with the validation and monitoring requirements of Article 7.4.18(c)(2) and Article 7.4.18(c)(3) of the CPDWR.

OTHER TREATMENT REQUIREMENTS

The Department is requiring that NSF55A UV reactors be preceded by an approved filtration technology providing *Giardia* and *Cryptosporidium* removal. Additionally, the Department requires that NSF55A UV reactors be followed by an approved chemical disinfection system providing 4-log virus inactivation. Non-NSF55A UV reactors can be validated for a wide range of dosages as provided by Article 7.4.18(c)(2) of the CPDWR; however, the Department is limiting the *Giardia* log-inactivation credit for NSF55A UV reactors to a maximum of 0.5-log and approving no log-inactivation credit for *Cryptosporidium* or viruses. Should a PWS wish to utilize a UV disinfection process for a greater log-inactivation credit, the UV reactor(s) will need to be validated in accordance the UVDGM and Article 7.4.18(c)(2) of the CPDWR.

In order for a water treatment process as a whole to provide a 4-log virus inactivation/removal, a total of 3.0-log *Giardia* inactivation/removal, and 2.0-log *Cryptosporidium* removal, filtration and chemical disinfection processes will be necessary in conjunction with NSF55A UV disinfection. The Department finds that by requiring filtration and chemical disinfection in conjunction with NSF55A UV disinfection, the multi-barrier approach to the approved log-inactivation credit are preserved.

DESIGN SUBMITTAL REQUIREMENTS

The acceptance of NSF55A UV disinfection for inactivation of *Giardia* applies only to the use of UV disinfection for compliance with Article 7 of the CPDWR. The acceptance does NOT constitute construction approval for installation or use at individual public water systems. Public water systems must submit plans for individual review and approval to use UV technology as a means of complying with Article 7 of the CPDWR. In addition to the plans submittal requirements outlined in the Design Criteria, the submittal must contain the additional information included in Table 8.

Table 8 – UV Disinfection Design Submittal Requirements

Parameter	Requirement
Certification of UV Disinfection Reactor	Certified for conformance with NSF/ANSI Standard 55 Class A. Manufacturer's operation and maintenance manual including raw water quality parameter limitations and installation requirements must be submitted
Raw Water Quality[1,2]	• UV transmittance (UVT) – must span different seasonal conditions where applicable (winter, runoff, summer) • Manganese (dissolved) • Iron (dissolved) • Hardness
Disinfection Goal	Submittal must verify that only *Giardia* is being targeted for UV inactivation. Additionally the submittal must identify what magnitude of log inactivation credit is being sought for the UV disinfection process individually and the overall treatment process as a whole. The maximum *Giardia* UV inactivation credit that will be granted is 0.5-log.
Process flow rate through UV reactor	Less than or equal to the NSF/ANSI Standard 55 Class A certified flow for the UV reactor specified
Hydraulics	Either 5 pipe diameters straight pipe upstream of the UV reactor or equal to or in excess of the manufacturer's installation guidelines
Design Flow rate (gpm)	Submittal must indicate the design flow rate for the UV reactor. Department approve flow rates will be less than or equal to the manufacturer's certified flow rate for the reactor specified.

Parameter	Requirement
Flow Measurement	Instantaneous flow measurement is required on all UV installations being used for log-inactivation credits
Flow Restriction	Flow restrictor devices are required on all UV installations to prevent flow through the reactor greater than the approved rate
Power Failure Flow Prevention	Flow prevention devices (i.e., solenoid valve) shall be installed to automatically close upon a power failure condition to prevent water from flowing through an unpowered UV reactor.
Sleeve and/or Lamp cleaning strategy	The submittal must contain a description of the procedure for cleaning the lamp and/or sleeve. This procedure must be included in the operations and maintenance manual
UV sensor calibration strategy	Sensor calibration verification is required on a monthly basis. Duty sensors can be compared to a reference sensor using the UV equipment control panel display indicating a discreet measurement of UV intensity and/or dose.
Alarm and Shut-off	The UV reactor must be equipped with an alarm function that is coupled with an automatic shut off device. The alarm and shut-off function must automatically operate when the UV dosage falls below the NSF/ANSI Standard 55 Class A limit of 40 mJ/cm^2. This failure condition must be tested by the PWS and documented at least once per calendar week that the UV reactor is in operation.
Redundancy and/or Contingency Plan	The submittal must contain a description of equipment redundancy or a contingency plan for emergency operations when the UV reactor is out of operation due to an alarm condition, cleaning, and or other unforeseeable events whereby UV disinfection is unavailable. At a minimum, spare UV bulbs and UV sensors must be kept onsite.

[1] *"Raw Water Quality" means water entering the UV reactor which may be raw, settled or filter effluent*
[2] *Water quality parameters must be within the manufacturer's specified range*

7. REGULATORY REQUIREMENTS

This section discusses the monitoring and record keeping activities expected by the Department for UV facilities. PWSs must monitor their UV reactors to determine if the reactors are operating within validated conditions. According to the UVDGM this monitoring must include:

- UV intensity as measured by a UV sensor
- flow rate
- lamp status
- and other parameters designated by the Department.

In addition to monitoring operational parameters, PWSs must verify the calibration of UV sensors in accordance with a protocol that the state approves [40 CFR 141.720 (d)(3)].

UV SENSOR CALIBRATION

The UV sensor(s) supplied with the NSF55A UV reactors will be calibrated initially by the manufacturer. According the UVDGM, UV sensors will drift out of calibration over time. Proper calibration and operation of the UV sensor(s) are essential to confirm disinfection performance of the UV reactor. The UVDGM indicates that "water systems must verify calibration of UV sensors with a protocol that the state approves [40 CFR 141.720(d)(3)]". Calibration monitoring involves first measuring UV intensity with the "duty" sensor, then the duty sensor is replaced with the "reference" sensor and UV intensity is measured again. If the difference between the two measurements is less than 20 percent, then the duty sensor is deemed to be in calibration. If the difference is greater than 20 percent, replacement of UV sensor(s) is required. The UVDGM recommends that calibration of duty sensors be verified with reference sensors at least monthly.

This UV sensor calibration requirement can be met by NSF55A units provided that a UV sensor monitor is included in the installation. This monitor, which provides an on-line readout of actual UV intensity and/or dose delivered, may be an optional additional piece of equipment not part of the UV reactor's standard package.

The procedure for checking the UV sensor calibration would involve recording the UV dose/intensity measured by the "duty" UV sensor. Then, removal/replacement of the duty sensor with a "reference" sensor would be accomplished and the dose/intensity recorded. In many cases, in order to accomplish this testing the PWS will be required to purchase a "reference" or back-up UV sensor and the optional communications equipment which allows for a UV dose/intensity measurement display.

OFF SPECIFICATION EVENTS

According to CWPDR Article 7.4.18(c)(3)(i), PWSs must treat at least 95 percent of the water delivered to the public during each month by UV reactors operating within validated conditions for the required UV dose to receive disinfection credit for UV treatment. Operating outside the validated limits is defined as "off-specification". Off-specification compliance is based on the volume of water treated. According to the UVDGM, UV reactors are operating off-specification when any of the conditions in Table 9 occur. Table 9 also includes a note for each parameter indicating how it may be applicable to or impacted by the operation of NSF55A UV reactors. Refer to UVDGM Section 3.4.1 for more information.

Table 9 – Off-Specification Conditions for NSF55A UV Equipment

Parameter	Off-Specification Condition	Note re: Relevance for NSF55A units	Can Design and Operation of NSF55A System prevent "off-certification" condition?
Flow rate	Higher than validated range	Flow restrictor prevents excess flow. PWS to record flows in Monthly operating reports.	YES. via flow restrictor
UVT	Lower than validated range	UVT is not measured on-line for NSF55A units. If UVT drops enough to trigger dose alarm the UV system will be automatically disabled.	YES. via dose alarm & shutdown
UV Intensity	Below validated setpoint	IF UV intensity drops enough to trigger dose alarm the UV system will be automatically disabled	
Validated Dose	less than the required UV dose at a given flow rate	IF UV dose drops enough to trigger dose alarm the UV system will be automatically disabled	
Lamp Status	One or more lamps that should be energized are not in service	NSF55A units are not designed for variable lamp status operation. Therefore, any lamp failure will trigger the dosage alarm and the UV system will be automatically disabled.	
Power failure	All UV lamps are off because of a power interruption or power quality problem, and water is flowing through the reactors	Department approval conditions provide for flow prevention devices to activate in the event of a power failure.	YES. via power failure flow prevention valve
UV Sensor Calibration	UV sensors are not within calibration criteria and the remedial actions are not taken	UV sensor calibration must be measured by PWS operator	NO. UV sensor calibration and recording must be used to verify off-specification performance
UVT Analyzer Calibration	UVT analyzer is out of calibration and corrective action was not taken	UVT is not measured on-line for NSF55A units because dose-monitoring approach is not allowed.	N/A for NSF55A units
Replacement Equipment	UV equipment includes installed or replaced components (or both) that are not equal to or better than the components used during validation testing	Replacement equipment is subject to manufacturer's requirements	NO. Replacement equipment is subject to manufacturer's requirements

Reference: UVDGM Section 3.4.1

ADDITIONAL MONITORING REQUIREMENTS

PWS's must keep monthly records of the following operational parameters and frequencies as shown in Table 10. These records must be kept onsite and available for review during Sanitary Surveys.

Table 10 – Monthly Monitoring and Reporting Requirements for NSF55A UV systems

Parameter or Function	Frequency of Monitoring	Note
Daily Flow through Reactor	Daily	Cumulative volume measured in gallons-per-day
UV Dosage Alarm and Automatic Shut-Off Equipment	Daily	UV dosage alarm and automatic shut-off equipment must be tested daily per the manufacturer's directions. Records documenting the date and result of such testing shall be maintained
Power Failure Flow Prevention	Daily	Flow prevention devices must be tested daily. Records documenting the dates and results of such testing shall be maintained.
Monthly volume of water treated	Monthly	Cumulative volume measured in gallons-per-month
Off-specification[1] flow percentage	Monthly	Percentage of flow that passed through the reactor when reactor was operating "off-specification"[1] - 95 percent of water treated monthly must not be through an "off-specification reactor"
UV Sensor Calibration	Monthly	Record date and result of sensor calibration verification. Record "duty" sensor reading and "reference" sensor reading and relative difference. Sensor replacement is required if variation exceeds 20 percent. Furthermore, all water treated when sensor calibration is greater than -20% is considered "off-specification" and must be reported as such.
O&M Data	Varies	Records of lamp run times, cleaning frequencies and other maintenance activities documenting the date and extent of activities shall be maintained.

[1] "Off-specification" flow can occur via one of three ways: 1) Flow through the reactor at a rate in excess of the certified reactor capacity, 2) Flow through the reactor when the UV sensor measurement validity is in question and 3) Flow through the reactor when the alarm/fail-safe function is not operating correctly. These events must be recorded in the monthly operating log and reported to the Department.

An example monthly record keeping and reporting form for "off-specification" performance is included in Table 11 and an example daily operating log is included in Table 12 on the following pages.

Table 11 - Example Monthly "Off-Certification" Monitoring Form

NSF55A UV MONTHLY MONITORING AND REPORTING FORM

Reporting Period: _____

System/Treatment Plant: _____

PWSID: _____

Operator Name: _____

Operator Signature: _____

Date: _____

UV Reactor (i.e., UV No.1, UV No.2, etc.)	Total Production (gallons)	Number of Off-Specification Events	Total Off-Specification Volume of Water (gallons)
TOTALS			

Compliance Certification

Total Volume of Off-Specification Water Produced (gallons) [A] _____

Total Volume of Water Produced (gallons) [B] _____

Percentage of Off-Specification Water Produced ([A] / [B] * 100) _____

Number of UV Sensors in use: _____

Date of UV Sensor Calibration test: _____

Percentage Difference in Calibration: _____

Was Calibration Difference less than 20% (Y/N) _____

If Calibration Difference is >20%:

Was UV Sensor Replaced? (Y/N) _____

Volume of water treated by reactor with UV sensor out of calibration? (gallons) _____

Facility Meets Off-Specification Requirements (<5% of Volume on a Monthly Basis) (Y/N) _____

Table 12 - Example Daily Operating Log

DAILY OPERATING LOG FOR NSF55A UV DISINFECTION EQUIPMENT

Reporting Period: _____

System/Treatment Plant: _____ UV Reactor ID: _____

PWSID: _____ Maximum Validated Flow: _____

Operator Name: _____

Operator Signature: _____

Date: _____

Day	Total Production (gallons)	UV Reactor Flow Rate (gpm)	UV Dosage Alarm & Shut off Operating Properly (Y/N)	Power Failure Flow Shut off Operating Properly (Y/N)	Was there any Off-Specification Flow (Y/N)	Total Flow Off-Specification (gallons)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
MIN						
MAX						
TOTAL						

[1] Off-Specification flow results when reactor flow is greater than certified flow, alarm shut-off function is not operating and/or power failure flow shut off is not operating. Off-specification flows must be reported to CDPHE-WQCD

8. CONCLUSION

The certification requirements of NSF/ANSI Standard 55 Class A are not the same as the validation requirements for UV reactors as specified by the UVDGM. Therefore, the NSF55A "certified" dose of 40 mJ/cm^2 cannot be considered a "validated" dose under the provisions of UVDGM. However, if the reduction factor (validation factor) guidance in the UVDGM is applied to the NSF55A procedure and conservative estimates of validation factor parameters are used, the 40 mJ/cm^2 NSF55A dose is considered by the Department to be a "WQCD Validated Dose" of 1.5 mJ/cm^2. This dose is sufficient to provide 0.5-log inactivation of *Giardia*.

The Department recognizes that the widespread availability and low cost of NSF55A UV reactors make them attractive to small public water systems for use in complying with the log removal requirements of Article 7 of the CPDWR. The UVDGM allows for the validation of NSF55A units provided they are evaluated on a case-by-case basis (UVDGM Section 5.2.2). The Department finds that use of NSF55A UV reactors may be approvable with certain limitations on the level of log-inactivation credit for *Giardia* required (0.5-log maximum) when Department-approved filtration processes and chemical disinfection processes precede and follow the UV disinfection equipment.

Table 1.4 of the UVDGM indicates that a UV dose of 1.5 mJ/cm^2 is sufficient to provide a 0.5-log reduction for Giardia. The Department will limit approval of NSF55A UV equipment to a maximum of 0.5-log *Giardia* inactivation credit provided that the other limitations and conditions described in this paper are met. The Department will approve NSF55A UV disinfection processes for treatment plants up to a maximum capacity of 100 gpm. For treatment plants with capacities greater than 100 gpm and source waters with a classification other than Bin 1, UV disinfection processes must comply with the validation and monitoring requirements of Article 7.4.18(c)(2) and Article 7.4.18(c)(3) of the CPDWR.