AquiSense Technologies

PearlAqua Micro™

User Manual

Models B & C

Aug 2023

Features

- Delivers UV Doses up to 70 mJ/cm^2
- Water flow rates up to 9 lpm
- High pressure, 120 psi, rated
- Fully integrated, super-compact design
- 12 or 24 V DC operation available
- Integrated temperature sensing
- Optional UV Intensity and LED Health sensor outputs
- Instant On/Off operation with unlimited cycling
- Mercury-free
- Operational lifetimes up to 10,000 hours
- Low hydraulic head-loss
- Compatible with push-to-connect fittings

Applications

- Commercial water dispensers
- Recreational-vehicle water treatment
- Residential under-sink installs
- Solar powered water disinfection
- Pharmaceutical point-of-use disinfection
- Water storage biofilm prevention

Product Examples

PAQ-12C-450-T0S-1148-S1000

- 30 mJ/cm^2 at 3 lpm
- 12V, 12.4W, UV intensity sensing

PAQ-03B-470-T00-2142-S1000

- 40 mJ/cm^2 at 0.5 lpm
- 24V, 2.6W, thermal sensing

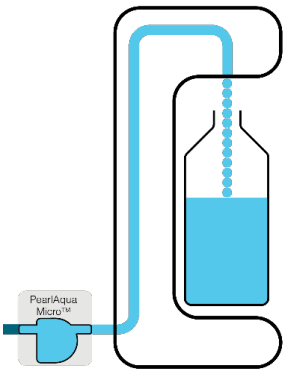
Description

The PearlAqua Micro product lines combine best-in-class UV LEDs with Aquisense's industry leading product designs. The compact size of these products enable UV water disinfection to be fully integrated into areas never-before possible.

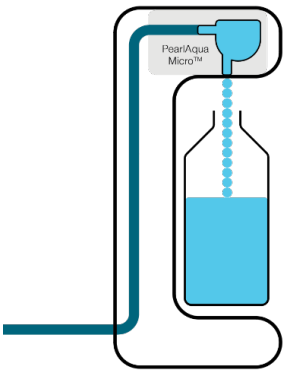
Aquisense's proprietary UV disinfection reactor designs enhance the instant-on / instant-off benefits of UV-LED systems allowing for highly energy-efficient water treatment.

Integrated UV-intensity sensing, temperature sensing, and UV-LED health sensing provide real-time monitoring of product function without the need for additional components.

Inlet Disinfection



Point-of-Consumption Treatment



1. Table of Contents

2. Safety

This device produces harmful ultraviolet (UV) radiation. Direct contact with UV radiation could damage the eyes and/or skin. Do not look directly into inlet or outlet ports without the use of UV resistant safety glasses.

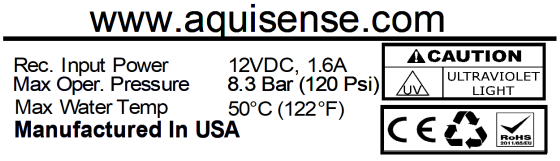
UV Exposure Risk

General

- Do not exceed absolute maximum ratings as outlined in this document
- This product is intended for the treatment of water and may cause unintended photochemical reactions in other substances allowed to pass through it
- No user-serviceable parts, do not disassemble
- Do no look into inlet or outlet ports while device is powered
- Always disconnect power from the unit before performing any type of maintenance or servicing
- Do not operate product without first connecting water supply and allowing water to flow through product
- Do not use the unit if there is any sign of damage
- Do not install the unit in an area subject to full sunlight
- Not a toy, keep out of reach of children
- Always comply with local plumbing and electrical codes
- FCC: Exempt under 15.103(c) and/or 15.103(d)
- ISED: Exempt under ICES 3 and 5 categorization
- CE: Exempt from Low-Voltage-Directive, EMC exempt
- For supply with safety extra-low voltage only, as per IEC 60335-1:
    - Voltage not exceeding 42 V between conductors and between conductors and earth, the no-load voltage not exceeding 50 V,
    - When safety extra-low voltage is obtained from the supply mains, it is to be through a safety isolating transformer or a convertor with separate windings, the insulation of which complies with double insulation or reinforced insulation requirements.

Safety Label

Verify that installation environment abides by these maximum limits.



3. Installation

PearlAqua Micro B and C models installed in preferred orientation

General Recommendations

- Read all installation instructions before beginning.
- **Do not apply power to the PearlAqua Micro without flowing water.**
- Install according to all local plumbing and electrical regulations.
- Review all Absolute Maximum Ratings in Section 4.
- Review locations of Inlet and Outlet water connections in Section 5.
- When choosing an installation location consider ease of access, maximum tube length, minimum tube bend radii, proximity to electrical connections and air circulation.
- Choose mounting orientation to avoid air bubbles from being trapped within the product. Inlet downwards and Outlet upwards is preferred, contact Aquisense for more information.
- Do a test fit of all components before install.
- Select appropriately sized tubing for fittings, Polyethylene or Nylon tubing should be used.

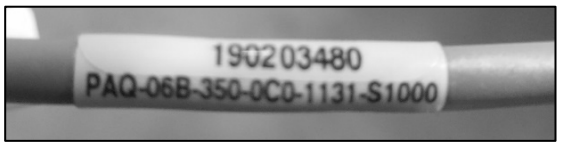
Procedure

1. Remove PearlAqua Micro from packaging, ensure contents are complete.
2. Turn off water to plumbing where the device will be installed
3. Attach Inlet and Outlet fluid connections using the appropriate fittings
    a. Push-to-connect fittings are recommended
4. Turn on water and allow flow through system, check and correct any leaks
5. Installation is finished, to activate UV disinfection simply apply power to the PearlAqua Micro. **Power should only be applied while water is flowing.**
    a. For automatic On/Off control when water is flowing, inquire with Aquisense about the PearlAqua AutoMate product

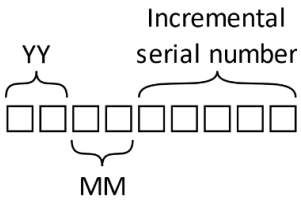
4. Product Identification

Each PearlAqua Micro is labeled with a unique serial and model number. This label is typically located on the wire harness

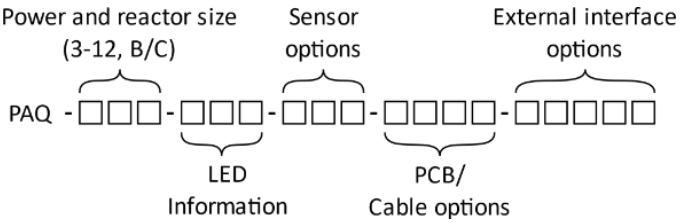
NOTE: Not all feature combinations available



Serial Number



Model Number



Power and reactor size

03B, 06B, 03C,
06C, 09C, 12C

Sensor options

Thermistor	LED Health	UV Intensity
0: No T: Yes	0: No C: Low Range H: High Range	0: No S: Yes

LED Information

UV-LED Type	UV-LED Current	Visible LED
0: No UV 2: Variant A 3: Variant B 4: Standard 5: Variant C	3: Low 5: Mid 7: High	0: None 1: Blue

PCB / Cable options

Voltage	Cable Length	Cable Cores	Cable Connector
1: 12 V 2: 24 V	1: 150mm 2: 300mm C: 500mm F: 1000mm 5: 1200mm	2: 2 conductor 3: 3 conductor 4: 4 conductor	1: Flying leads 2: Barrel Plug 8: JST XHP F: Molex Mini-Lock X: Non-Standard

External interface options

Enclosure	Fluid Connection	Flow Switch	External Indicator Board	Special Build
S: Standard H: Horizontal X: Other	1: 3/8” 2: 11mm 3: 1/2" 4: Other	0: None S: Integrated B: Bracketed	0: No 1: Yes	0: No 1: Yes

5. Technical Specifications

Recommended Operational Conditions

Parameter		Value	Unit
Input Voltage	12V models	12	Volt
	24V models	24	
Flow Rate[1]		1 (0.26)	lpm (gpm)
Water Temperature		25 (77)	°C (F)
Ambient Temperature		25 (77)	°C (F)
UV Transmittance[2]		>90	%
Particulate Size		<10	micron
Hardness		<(7/120)	mg/L
Iron		<0.3	ppm

(1) Flow rate varies by model number and desired UV dose. See **Performance Graphs**
(2) Defined as % of 254nm UV power retained over a 1-centimeter path length

Absolute Maximum Ratings

Operating the device outside these conditions may cause permanent damage.

Parameter		Min	Max	Unit
Input Voltage	12V models	-13.3	13.3	Volt
	24V models	-26.7	26.7	
Operating Pressure			8.3 (120)	bar (psi)
Water Temperature	B models	0 (32)[1]	50 (122)	°C (F)
	C models		45 (113)	
Ambient Temperature			80 (176)	
UV Intensity Sensor Pin Voltage		-0.7	30	V
LED Health Sensor Pin Current		-5	5	mA

(1) Freezing of water within the device creates a risk of rupture

Electrical Specifications

Parameter	Conditions	Min	Typ	Max	Units
Input Voltage	12V models	11.4	12	13	V
	24V models	21.6	24	25	
Power Consumption	See model characteristics table				
Input Capacitance	All models			4.7	uF
Inrush Current	12V models			2(6)	A
	24V models			3(6)	
Optional Power Supply(7)					
Input Voltage		90		264	VAC
Output Voltage			12		V
Output Power				19	W
Thermistor Sensor					
Resistance(1)	@25C		10		KOhm
B25/50			3380		K
B25/80			3435		K
Operating Range				55	C
LED Health Sensor					
Signal value(2)	UV-LEDs On(5)	8.5	10	10.5	V
	UV-LEDs Off		0	0.7	
Output Impedance		100	1000		Ohm
UV Intensity Sensor					
Signal value(3)	100% UV Output(4)		25	40	mA
	70% UV Output(4)		18		

(1) See **Section 9: Usage** for more details
(2) Applicable to device with High Range LED Health Sensor option only
(3) See **Section 9: Usage** for more details
(4) Clean reactor, >95% UVT
(5) Within 100ms of power application
(6) Voltage rise time=100ps
(7) 12V models only

Disinfection Specifications

Parameter	Conditions	Min	Typ	Max	Units
Operating Lifetime[1]	PAQ-xxx-43x, 25C[2]	10000			hours
	PAQ-xxx-45x, 25C[2]	8000			
	PAQ-xxx-47x, 40C[2]	2000			
UV Dose	See **Performance Graphs**				

(1) End of life defined as 70% of starting UV flux
(2) Temperature as reported by thermistor sensor

Mechanical Specifications

Parameter	Conditions	Min	Typ	Max	Units
Weight	B models, dry		77(2.7)		g(oz)
	C models, dry		162(5.7)		
Hydraulic Headloss[1]	B models			0.14(2)	bar(psi)
	C models			1(14.5)	
Internal Volume	B models		17		ml
	C models		47		
Ingress Protection	All models	IP68			

(1) 2 lpm, 3/8" fluid connection, vertical orientation

Regulatory Compliance

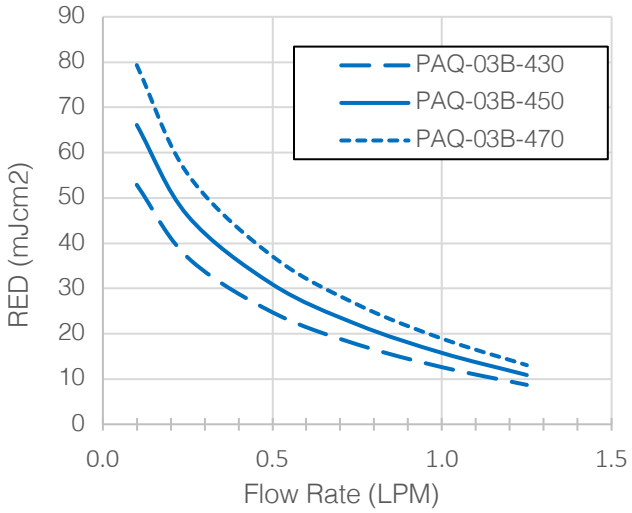
Regulation/Guideline	Status
NSF/ANSI 55:2019	Certified by NSF
WaterMark (AS/NZS 3497)	Certified by Global-Mark
IEC 60335	Certified by TUV Rhineland
ISO 9001:2015	Certified by Dekra
NSF REG4 (WRAS)	Certified
EMC (EN 55022)	Compliant
CE (2014/30/EU; 2011/65/EC; 2001/95/EC)	Compliant
RoHS 3 (Directive 2011/65/EU)	Compliant
REACH (EC No.1907/2006)	Compliant

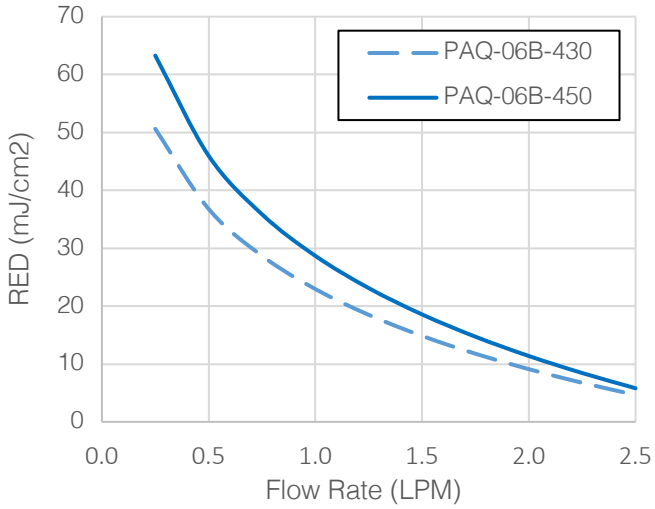
Model Characteristics

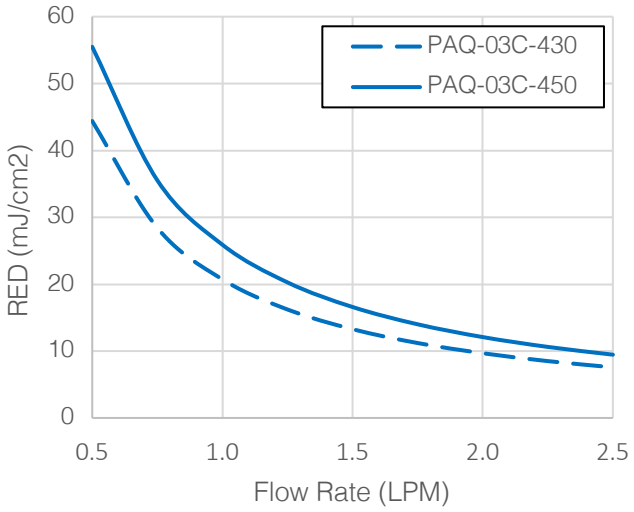
Model number(1)	Model voltage (2)	Power Consumption (Watts)(3)		
		Min	Typ	Max
PAQ-3B-x30	12V	1.8	2.2	2.7
PAQ-3B-x50		2.7	3	3.6
PAQ-3B-x70		3.6	4.6	5
PAQ-6B-x30		3.6	4.7	5.3
PAQ-6B-x50		5.5	7.3	7.6
PAQ-6C-x30		3.6	4.7	5.3
PAQ-6C-x50		5.5	7.3	7.6
PAQ-9C-x30		5.4	6	7.2
PAQ-9C-x50		7.8	8.9	12
PAQ-9C-x51		9.6	10.5	11.2
PAQ-12C-x30		7.2	8.4	9.6
PAQ-12C-x50		9.36	12.4	13.8
PAQ-3B-x30	24V	1.9	1.3	3.6
PAQ-3B-x31		1.5	1.8	2.2
PAQ-3B-x50		3.8	4	4.8
PAQ-3B-x70		3.8	2.6	6.5
PAQ-6B-x50		4.8	5.5	9.6
PAQ-6B-x70		Contact Aquisense		
PAQ-12C-x50		5.4	6.1	6.8

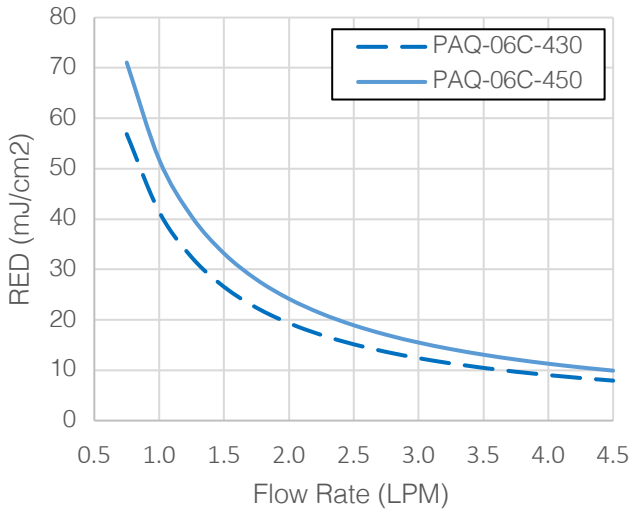
(1) “x” indicates wildcard value, only first 9 characters of model number considered
(2) as determined by part number
(3) Measured at recommended input voltage

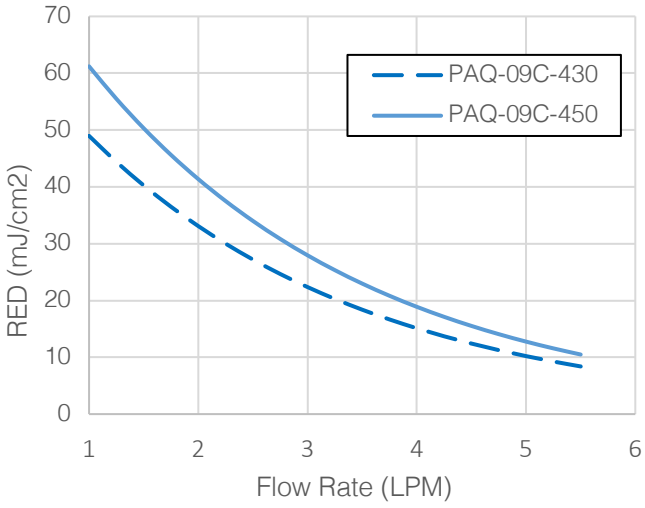
Performance Graphs

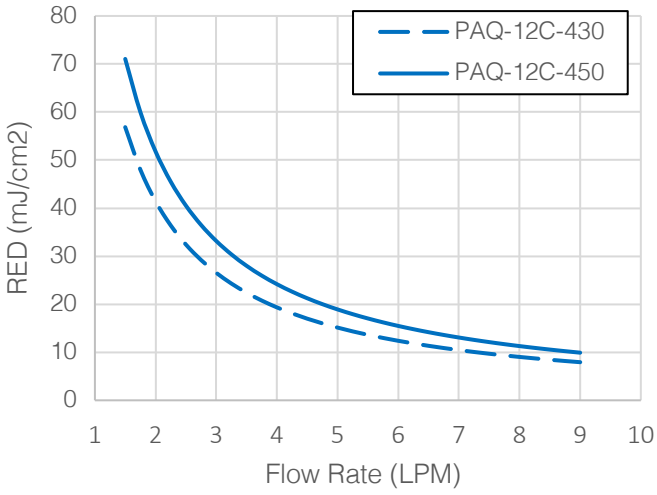


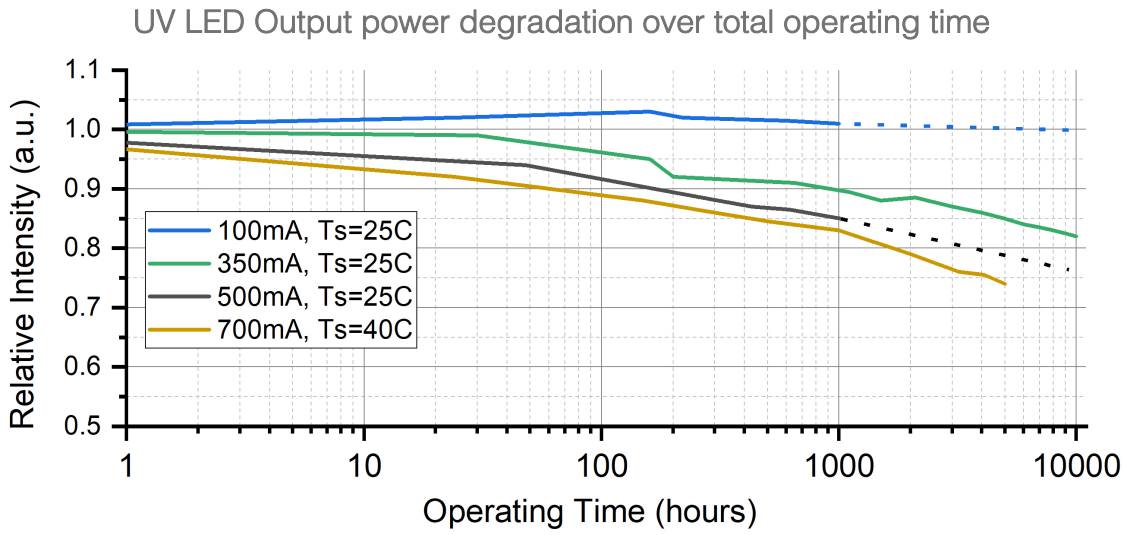


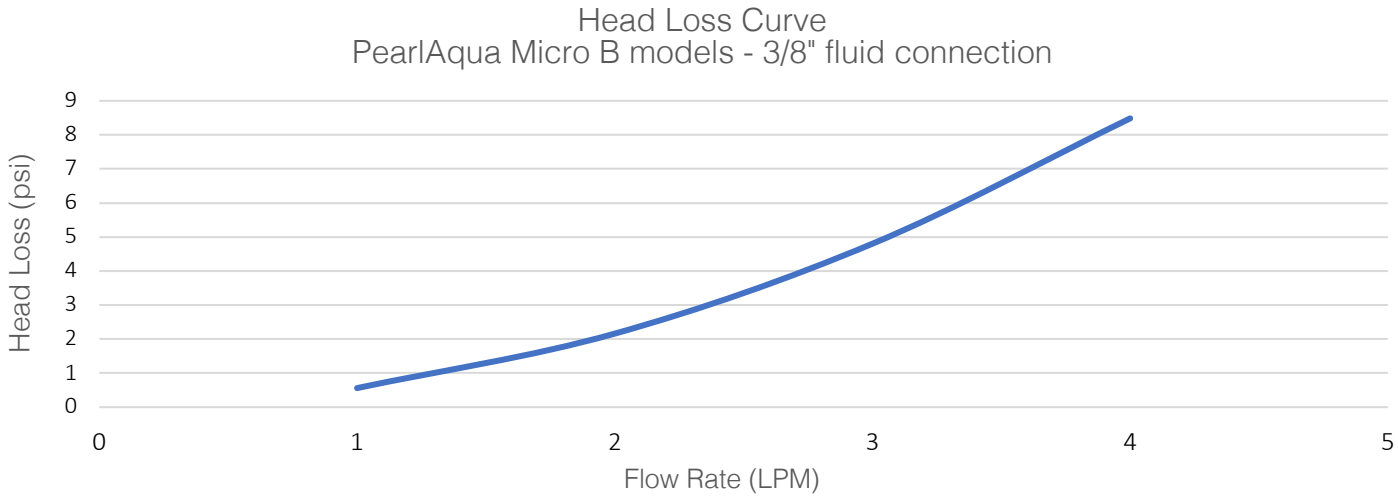


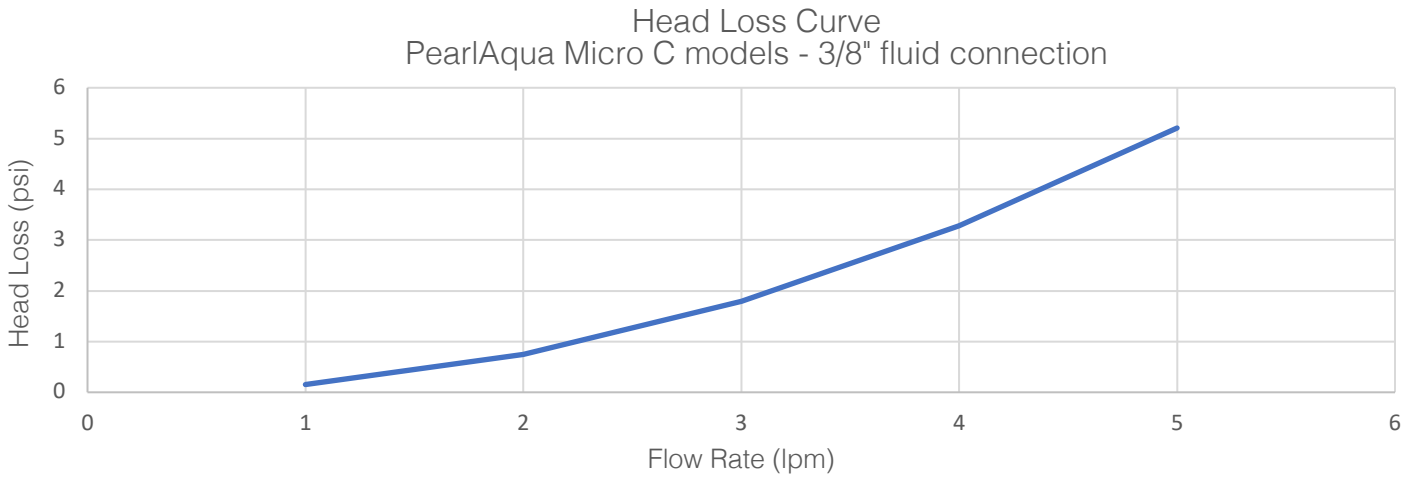







UV LED Output power degradation over total operating time
Relative Intensity (a.u.)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
100mA, Ts=25C
350mA, Ts=25C
500mA, Ts=25C
700mA, Ts=40C
1
10
100
1000
10000
Operating Time (hours)

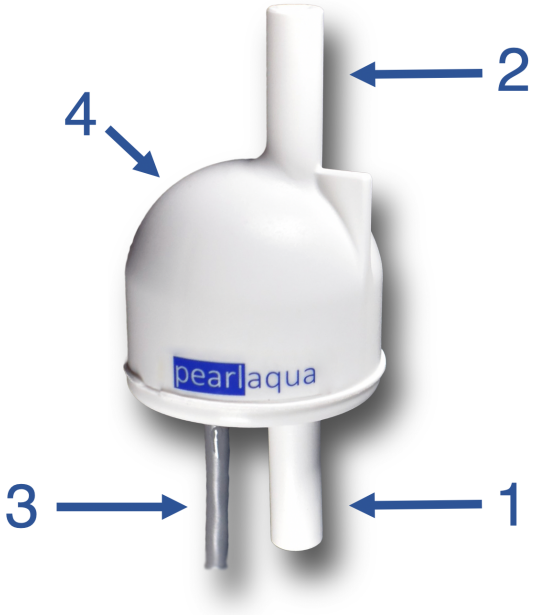

Head Loss Curve
PearlAqua Micro B models - 3/8" fluid connection
Head Loss (psi)
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
Flow Rate (LPM)


Head Loss Curve
PearlAqua Micro C models - 3/8" fluid connection
Head Loss (psi)
6
5
4
3
2
1
0
0
1
2
3
4
5
6
Flow Rate (lpm)

6. Components

B & C models

Standard Enclosure
3/8” fluid connections



C models

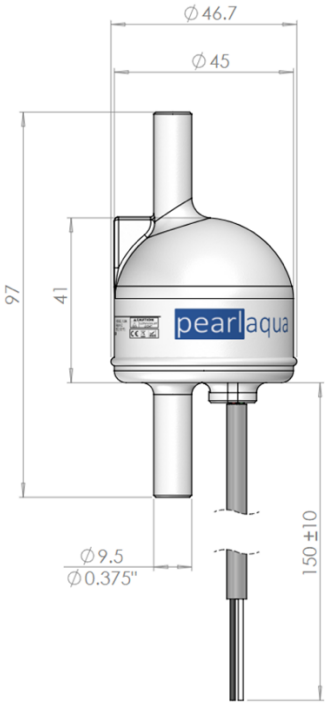
Horizontal Enclosure
3/8” fluid connections

ID	Name	Detail
1	Water Inlet	
2	Water Outlet	
3	Wire Harness	
4	Reactor Chamber	
5	Mounting bracket	2 x 5mm diameter mounting holes

7. Dimensions

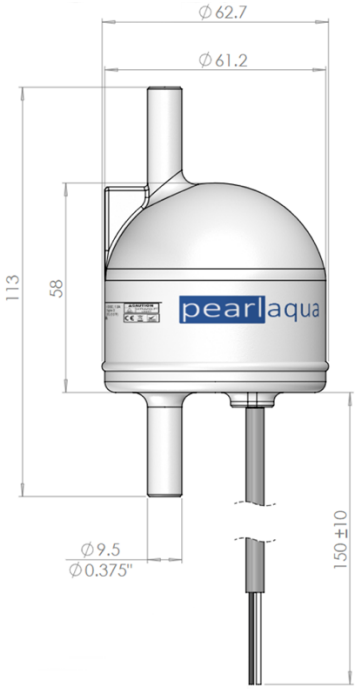
B models

Standard enclosure
3/8” fluid connection
Dimensions in mm



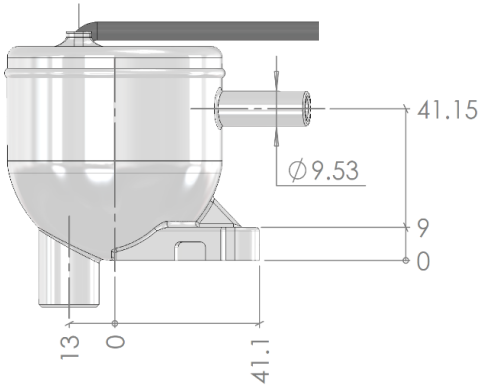
C models

Standard enclosure
3/8” fluid connection
Dimensions in mm



C models

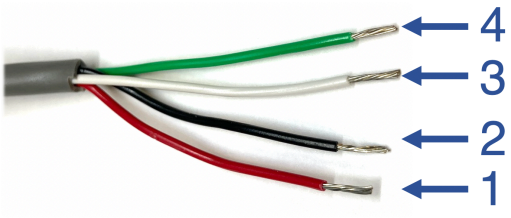
Horizontal enclosure
3/8” fluid connection
Dimensions in mm



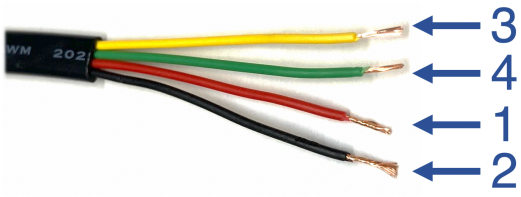
8. Pinout

NOTE: Alternate and custom configurations available

Flying Leads

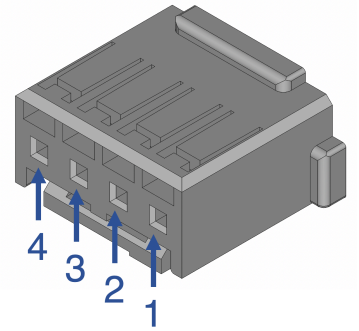


Wire gauge: 22 AWG



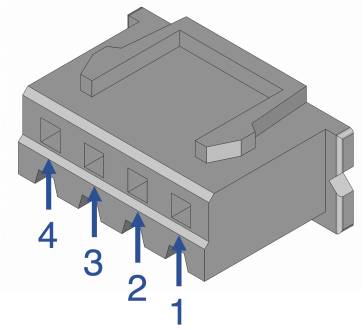
Wire gauge: 28 AWG

Molex Mini-Lock



Part number: 0511030400

JST XHP



Part number: XHP-4

ID	Name	Color	Description	
1	Vin	Red	Input voltage positive	
2	Gnd	Black	Input voltage ground / Common	
3	SensorA	White/Yellow	TH0, TC0 models(2)	LED Health Sensor
			T0S models(2)	UV Intensity Sensor
			T00 models(2)	Thermistor-
4	SensorB	Green	Thermistor+	

(1) 2 and 3-pin versions also available

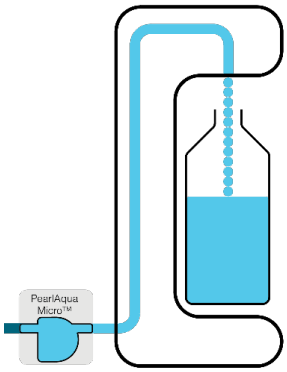
(2) See Sensor Options in **Section 3: Product Identification**

Barrel Plug

2.1mm x 5.5mm barrel plug
Center pin: Input voltage positive
Barrel: Ground

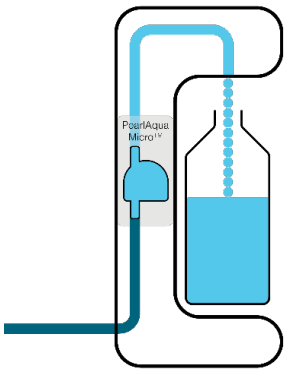
9. Usage

Example Applications



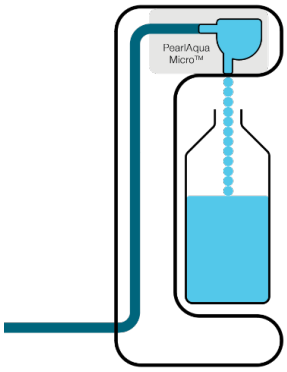
Inlet Disinfection

This method leaves the disinfection outside the device or process, leaving an opening for bacteria growth at any point in the system. The UV LED system is easier to replace but with lamp lifetimes of up to 10,000 hours, the need to replace is less frequent when compared to conventional mercury lamps. For example, 5,000 hours 'on' time at 2 LPM equals 600,000 liters of water served to clients. Inlet disinfection can also make installations easier as there is no need for a system redesign or remodeling of the original product. However, installing the UV LED system at the inlet can make for a more cumbersome system as your components are now outside and more likely to be damaged or disconnected.



In-Process Disinfection

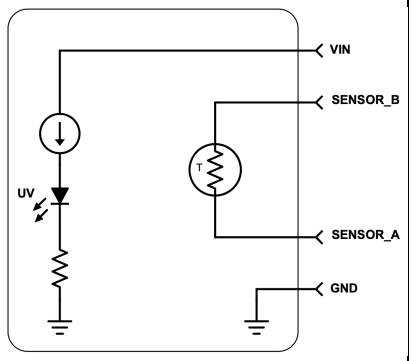
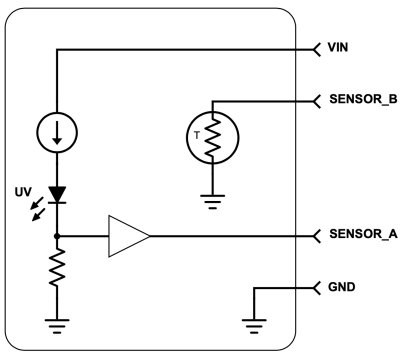
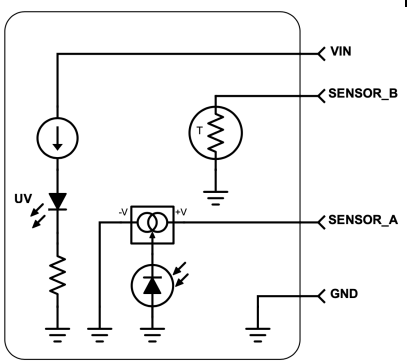
Installing a PearlAqua Micro offers added benefits as your product is now intact with no parts or components outside the system. This type of installation is closer to point of use as the amount of contamination possible from the point of use to the disinfection point has been diminished. One drawback is this type of installation does not prevent retro contamination, or bacteria growing up the pipeline from the point of use.



Point-Of-Consumption Disinfection

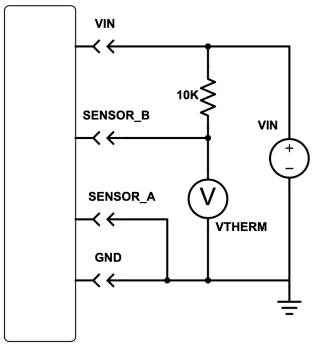
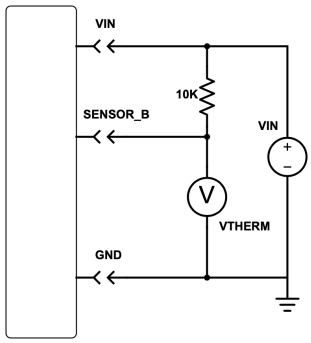
Point of consumption or point of use disinfection offers the most protection for contamination in a product or system. By installing a UV-C LED system at the point of consumption two major benefits are offered – retrograde protection and last mile protection. Retrograde contamination, as mentioned before happens when bacteria from the outlet contaminates the system by growing up the pipeline into the system. Retrograde protection offers disinfection at the outlet, so growth is prevented. One manufacturer who uses our product also improves on this concept by switching on the UV LEDs to periodically disinfect the outlet even when not in use. Last mile protection offers disinfection from pathogens that might be growing at any point prior to the outlet. Point of use protection allows the manufacturer an assurance of disinfection for the end user of their product.

Block Diagrams

T00 models(1)	TH0, TC0 models(1)	T0S models(1)
		

(1) See Sensor Options in Section 3: Product Identification

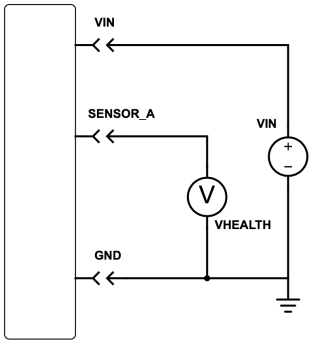
Thermistor Sensor

Thermistor Sensor Example Application	
T00 models	TH0, TC0, T0S models
	

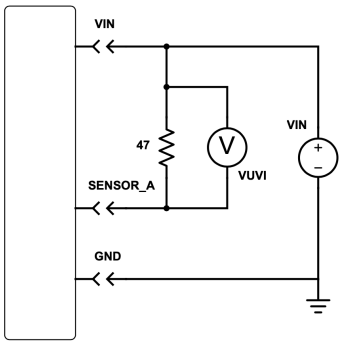
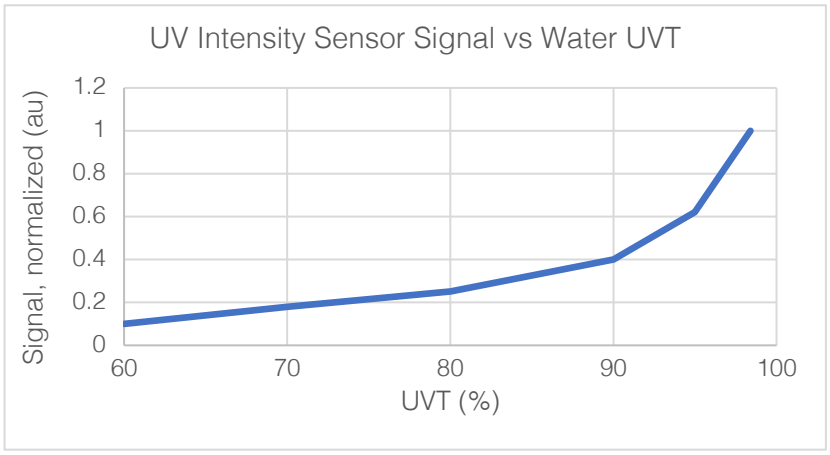
UV LED Temperature (C)	VTHERM (V)	
	VIN=12V	VIN=24V
25	6	12
30	5.4	10.8
40	4.4	8.8
55	3.1	6
60	2.8	5.6
70	2.2	4.4
80	1.8	3.6

NOTE: See **Section 4** for detailed thermistor performance specifications

LED Health Sensor

LED Health Sensor Example Application	
TH0 models	Notes
	• Refer to **Section 4** for expected VHEALTH values. • VHEALTH measurement method should have an input impedance exceeding 10K ohms. • Do not exceed 5mA current-input or current-draw from LED Health Sensor pin.

UV Intensity Sensor

UV Intensity Sensor Example Application	
	

When a voltage is applied to the Sensor_A pin, the UV Intensity Sensor will modulate the current draw into this pin according to the UV flux within the Micro PearlAqua. UV flux within the device is a function of UV LED output, water transparency, and reactor fouling. This current draw signal can be measured by using an ammeter or by placing a small sensor resistor (47 ohm recommended) in series with the Sensor_A pin and measuring the voltage drop across it.
Due to variation in manufacturing, each Micro PearlAqua should be individually calibrated in-situ using a known UVT.
If a low-UVT alarm function is desired, the Micro PearlAqua should be filled with water of the desired low-UVT value during calibration. The UV Intensity Signal would then be measured and this value stored as the setpoint below which the alarm would trigger. This method will yield the best accuracy.
Generally, differentiating between two UVT values becomes increasingly difficult the lower these value are. Choosing a setpoint between 70 to 85% UVT is recommended.

Preventing biofilm and retrograde contamination

In cases where the Micro PearlAqua may be left filled with water while inactive for long periods of time consider the following risks:

- Biofilm growth within Reactor Chamber
- Retrograde contamination migrating into the Reactor Chamber from upstream/downstream plumbing

To reduce these risks, the device may be operated for short periods without water flow.

It is necessary to monitor the thermistor sensor during this no-flow activation period in order to ensure the UV LEDs do not overheat. The thermistor reading should not be allowed to exceed 55 C.

Activating the device for 1 second every 30 minutes while monitoring thermistor temperature is a typically effective pattern.

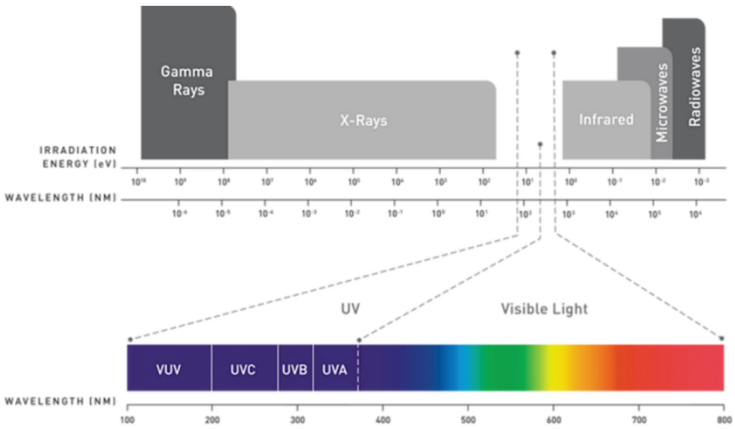
Troubleshooting

Issue	Possible Cause	Possible Solution(s)
Unit does not power on	Loose power connections	Verify all electrical connections are secure
	Low voltage or low current condition	Verify input voltage is within recommended ranges
Unit shuts down intermittently	Unit is overheating	Do not operate unit without water flow. Check Thermistor Sensor if equipped.
Unit is leaking	Unsecure plumbing connections	Verify connections are secure, use recommended tubing material i.e. polyethylene or nylon
	Improper connector sizing	Ensure connector size matches unit's Fluid Inlet/Outlet. Check metric vs Imperial units.
High pathogen counts	Low UV-Transmittance or other water quality issue	Verify water quality adheres to recommended values. Use pre-treatment if necessary.
	Bacteria from other portion of water system after UV i.e. tubing, connectors	Use new, clean tubing and connections. Flush system with hot water.
	Air bubbles trapped in unit	Verify device orientation according to installation procedure
	High flow rate	Refer to performance graphs for selected device model
	Lamp has reached end of life	Contact AquiSense for replacement
	Biofilm growth or retrograde contamination within unit	Ensure unit is being used regularly. If unit might have long periods without normal usage consider periodic pulsing of device.

10. Theory

UV-C Water Disinfection

Ultraviolet (UV) water disinfection technology has become an increasingly popular tool in water treatment over the past three decades, due in part to its ability to provide treatment without the use of harmful chemicals. UV represents wavelengths that fall between visible light and x-ray on the electromagnetic spectrum.



The UV range can be further divided into UV-A, UV-B, UV-C, and Vacuum-UV. The UV-C portion represents wavelengths from 200 nm - 280 nm, which is the wavelength range used in our LED disinfection products. UV-C photons penetrate cells and damage the nucleic acid, rendering them incapable of reproduction, or microbiologically inactive.

UV-C LEDs

A light-emitting diode (LED) is a semiconductor light source. It is a p–n junction diode, which emits light (or photons) when activated. The PearlAqua Micro utilizes small, state-of-the-art, UV-C LEDs, which emit photons in the UV range, to provide pathogen reduction without the use of harmful chemicals or heavy metals. Use of LEDs allows the PearlAqua Micro to achieve full intensity power upon start-up, withstand unlimited power cycles without impacting device life, and eliminate expensive disposal processes.

11. Warranty

General Statement of Warranty

The warranty period is 24 months from date of warranty registration, covering all failures due to material and product assembly. The owner must register the product at https://aquisense.com/registration for the warranty to be in place.

This warranty shall not apply to any failure or defect which results from the Equipment not being operated and maintained in strict accordance with instructions specified in the AquiSense Operations manual or defect which results from mishandling, misuse, neglect, improper storage, improper operation of the Equipment with other equipment furnished by the Owner or by other third parties or from defects in designs or specifications furnished by, or on behalf of, the Owner by a person other than AquiSense. In addition, this warranty shall not apply to Equipment that has been altered or repaired by anyone except AquiSense, their Authorized representative, or personnel acting under specific instructions from AquiSense.

The Owner must notify their dealer within 5 days of the date of any Equipment failure. This notification shall include a description of the problem, details of the product name (e.g. PearlAqua Micro), model number (e.g. 9C) and serial number - all found on the product label.

The Owner will fully cooperate with their dealer in attempting to diagnose and resolve the problem by way of telephone/web support. If the problem can be diagnosed by telephone/web support and a replacement unit is required, the dealer, in conjunction with AquiSense will either, at AquiSense expense, ship a repaired, reworked, or new part to the Owner. If the problem is not attributable to a breach of this warranty, the dealer or AquiSense reserves the right to invoice the Owner for this service.

This warranty is in lieu of all other warranties whether written, oral, implied, or statutory. Without limitation, no warranty of merchantability or fitness for a particular purpose shall apply to the Equipment.

Operating Hours

Unlike mercury vapour UV-C lamps, the lifetime of UV-C LEDs is not affected by on/off cycles. However, like all light sources, LEDs are subject to aging over time. AquiSense Technologies have engineered an integrated UV-C LED lamp module that contains: power regulation, temperature management, temperature monitoring, and intensity monitoring. When operated in accordance with AquiSense instructions, it is expected that the LED lamp module lifetime will be up to 5,000 hours depending on configuration.

Premature LED lamp module Failure

In the case of failure, the following refund/replacement applies:

- Up to 6 months use: Full Replacement
- Over 6 months use: Proportionate (Pro-rata) credit

Limitations of Warranty

This warranty:

- Relates only to faults in material and assembly. It does not cover any form of breakage from mishandling or mis-operation
- Applies where operating conditions are kept in accordance with AquiSense instructions
- Is limited to 24 months after the date of delivery
- Excludes transport costs for the return of parts
- AquiSense will not be responsible for any damages, consequential or otherwise

Return of Product

In all warranty cases, contact your dealer with details of the product name (e.g. PearlAqua Micro), model number (e.g. 9C) and serial number - all found on the product's cable. In case of difficulty, contact info@aquisense.com

Disposal of Product

As part of our commitment to the environment, all used or failed product returned to AquiSense facilities through your dealer will be properly recycled at no charge.

12. Legal

Terms for Product Usage

In using AquiSense UV-LED products and components, on behalf of the Company, using this document and the PearlAqua Micro product agrees to follow the items listed below. In this document, “UV LED” means any LEDs that emit ultraviolet light with a peak wavelength shorter than 400nm.

1. Do not look directly into the UV LEDs during operation. The UV LEDs radiate intense ultraviolet light (hereinafter referred to as “UV light”) which can be harmful to the eyes, even during a brief period of exposure. UV light is not visible to human eye, so individuals exposed to the UV light may not notice it.
2. Always wear UV protective eyewear when operating the UV LEDs.
3. UV light can cause skin damage, up to and including, skin cancer. Always wear protective clothing to prevent UV LED exposure to skin.
4. Always instruct and warn all intended users of proper handling of the UV LEDs and all potential hazards. Always provide proper instructions, labels, and warnings to the customers and users of products containing UV LEDs in accordance, at minimum, with the standards set forth by the International Electrotechnical Commission (IEC). All UV LED should be used in such a way as to ensure that no direct exposure to the UV light on the human eyes is experienced.
5. Always keep the products containing UV LEDs out of the reach of children and other untrained persons.
6. Always adhere to safety instructions and warnings, including any and all instructions set forth in the Product Specifications.
7. As applicable, user must provide adequate thermal management, electrical power, and safe mechanical integration.
8. If products and components are used outside the specified/recommended manner, the user accepts all risk for all damages or ineffective performance.

All relevant officers and employees at our Company have reviewed and understand all the safety instructions and warnings in connection with the purchase and use for AquiSense UV-LED products and components, and further agree not to hold AquiSense Technologies LLC and its partners, including but not limited to, Nikkiso America and Nikkiso Giken, responsible for any damage or injury caused by the use, misuse, or mishandling of any AquiSense UV-LED product or component.

13. Change Log

Vers	Table/Item Change	Date
6	New Format Release Updated Technical Specifications for all Products	Sept 19, 2022
8	Updated Power draw estimates for all models	August 29, 2023