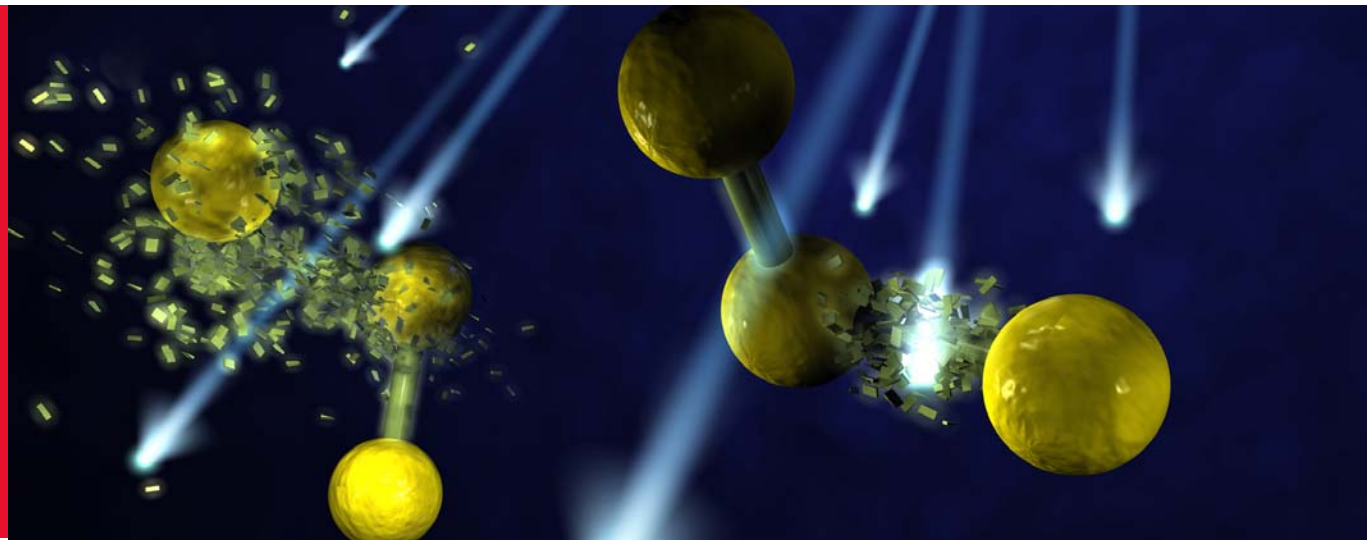
Clean & Safe Drinking Water Workshop
Gander, NL

UV SYSTEM MAINTENANCE & TROUBLESHOOTING



March 12th, 2008

By: Robert Gillis, P.Eng.
Atlantic Purification Systems

APS

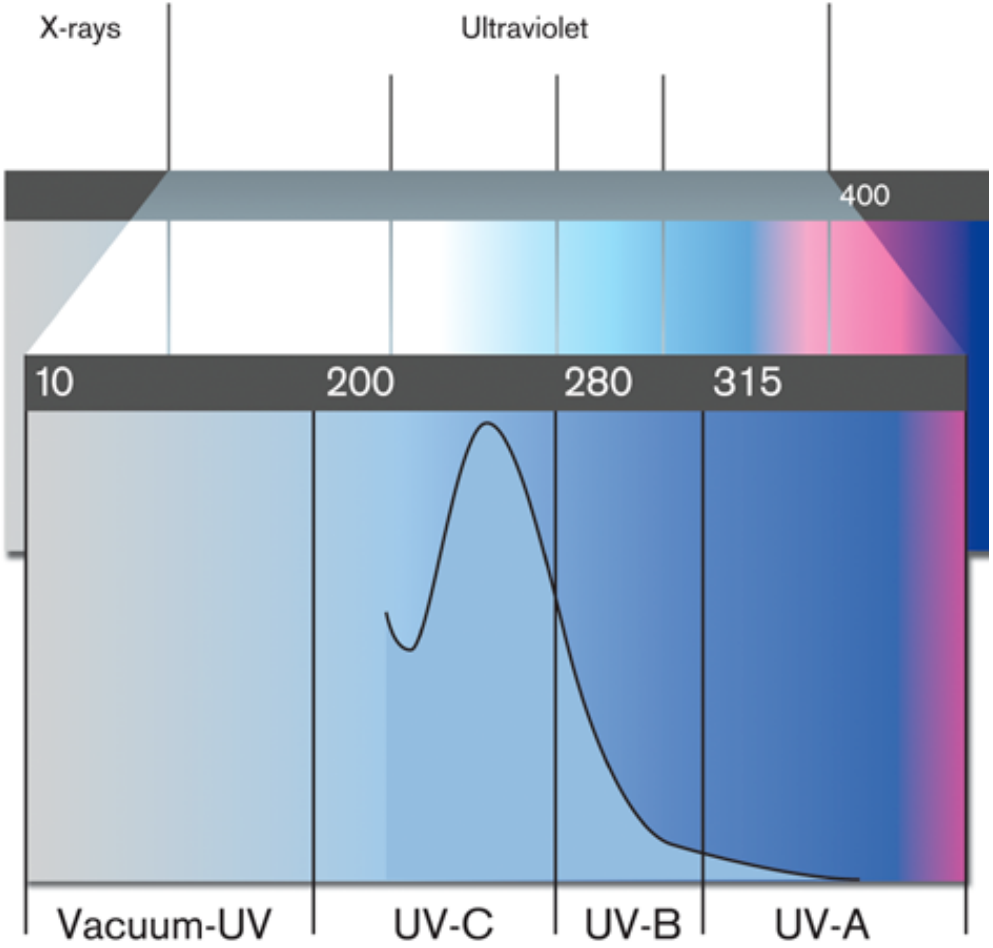
UV PRESENTATION AGENDA

- **Introduction to UV Light**
  - **UV Lamps, Advantages, Applications**
- **UV Dose**
  - **Calculation, Influencing Factors**
- **Design Criteria**
  - **UV Transmittance**
- **Key Components**
  - **Lamp Types, UV Intensity Sensor, Control Panel**
- **Operation**
  - **Recommended Actions**
- **Maintenance**
  - **Safety, Recommended Actions, Lamp Aging, Sleeve & Sensor Fouling, Spare Parts**
- **Troubleshooting**
  - **Types of Alarms**
  - **Common Alarms**

APS

TROJAN UV

INTRODUCTION ULTRAVIOLET (UV) LIGHT



Categories of UV Light

UV light is comprised of electromagnetic radiation of wavelengths ranging from 10 nm to 400 nanometers (nm)

UV-A (Long Wave UV): 315-400 nm

UV-B (Middle Wave UV): 280-315 nm

UV-C (Short Wave UV): 200-280 nm

Vacuum UV: 10-200 nm

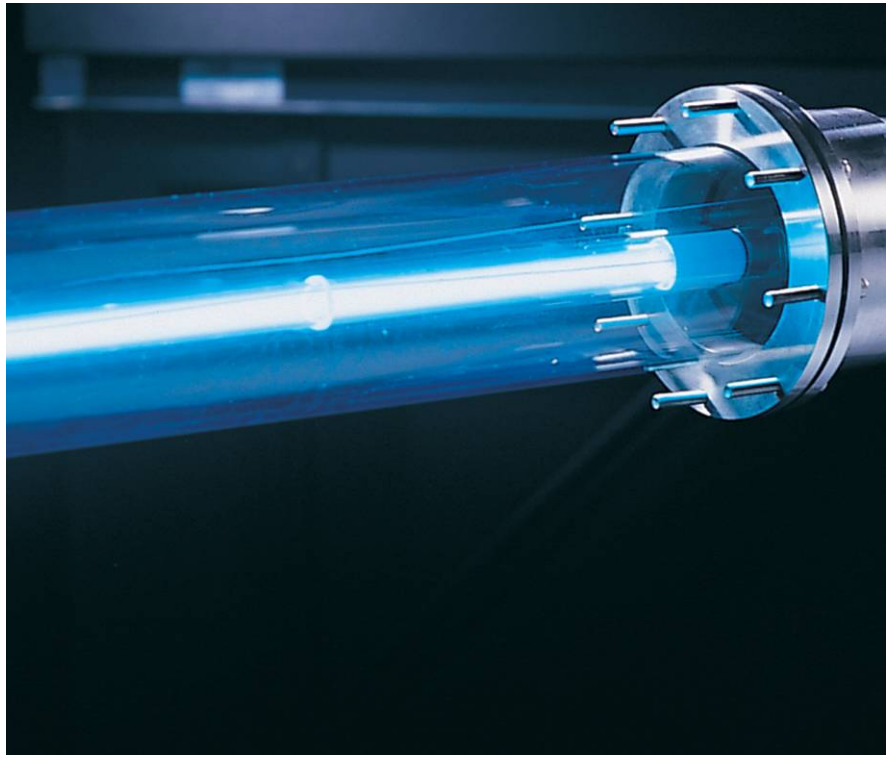
Germicidal Wavelength: 200-300 nm

APS

TROJAN UV

UV LAMPS HOW THEY WORK

1. Power is applied to the lamp electrodes
2. Electrical arc is generated from ionized gas or gas mixtures, which conduct electricity
3. Current is limited from the power source to protect the lamp and supply wiring
4. As the arc temperature rises, mercury in lamp converts to a gaseous vapor state
5. Mercury vapor conducts electricity, completing the circuit
6. UV light photons are released as vapor conducts electricity



APS

TROJAN UV

UV LIGHT ADVANTAGES

Fast acting
Application of UV light triggers a reaction almost instantly

No disinfection by-products
UV light does not result in the creation of harmful disinfection by-products

Safe and chemical-free
UV does not introduce any of the hazards associated with chemicals, such as handling and disposal. It is an environmentally responsible and increasingly championed technology

No chemical addition to water
UV does not alter water chemistry and its constituents, such as pH, taste, odor, color, etc.

Proven and trusted
UV is widely used to disinfect drinking water and wastewater worldwide, and has been for many years. UV is also extensively used for industrial applications including food & beverage, pharmaceutical, and semiconductor manufacturing

APS

TROJAN UV

UV APPLICATIONS DISINFECTION

How Does UV Disinfect?

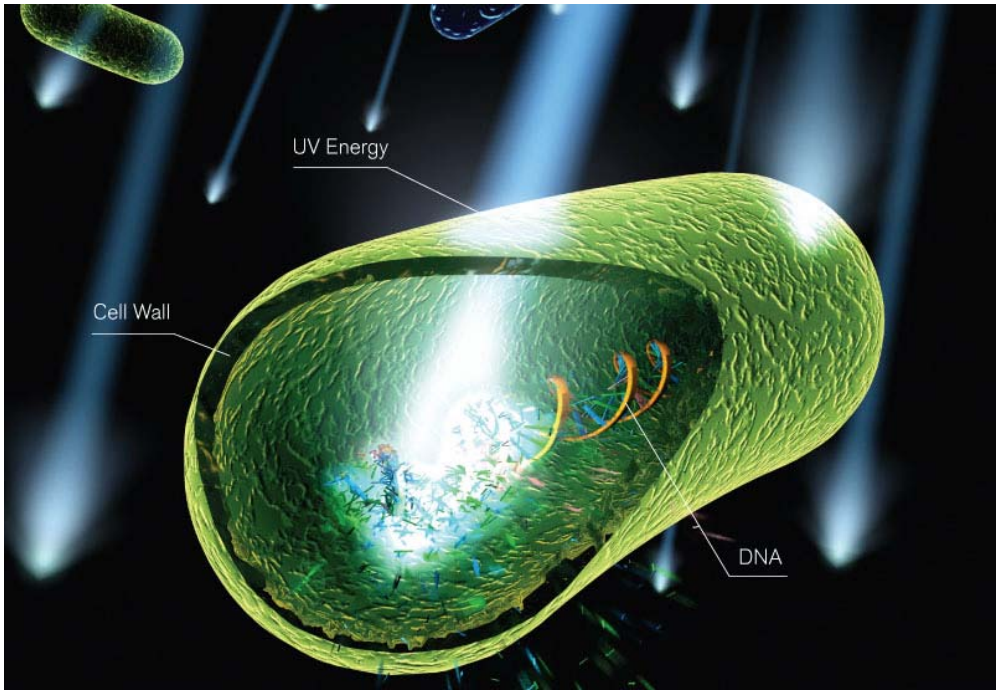
UV light penetrates the cell wall of the microorganism

The amount of UV delivered to the organism is called the intensity

Cell damage depends on the **Dose** of UV absorbed & the microorganisms resistance to UV

The UV energy permanently alters the DNA structure of the microorganism in a process called *thymine dimerization*

The microorganism is “inactivated” and rendered unable to reproduce or infect



APS

TROJAN UV

UV DOSE CALCULATION

UV Dose is a product of:

Intensity (quantity of UV light per unit area) **and**
Residence Time (contact time in the reaction chamber)

UV DOSE = Intensity X Residence Time

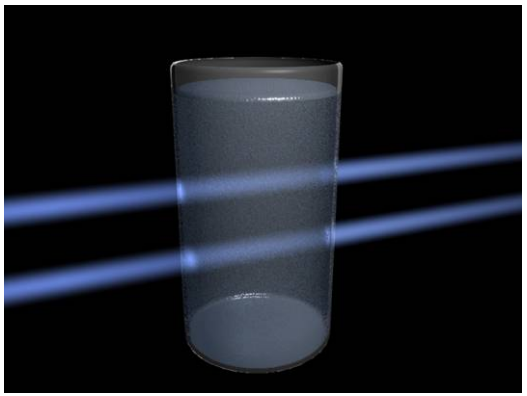
UV Dose is expressed in: µWsec/cm^2 (Microwatt seconds/cm^2)
mWsec/cm^2 (Milliwatt seconds/cm^2)
mJ/cm^2 (Millijoules/cm^2)

APS

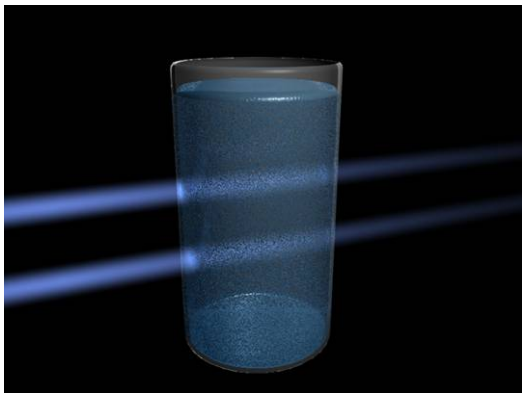
TROJAN UV

UV DOSE INFLUENCING FACTORS

Water Clarity (UVT)

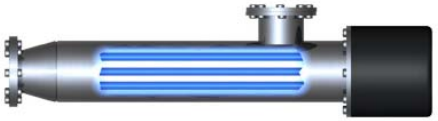


High UVT = High Dose



Low UVT = Low Dose

Flow Rate



Fast Flow = Low Dose

Slow Flow = High Dose

APS

TROJAN UV

UV DOSE WATER QUALITY FACTORS

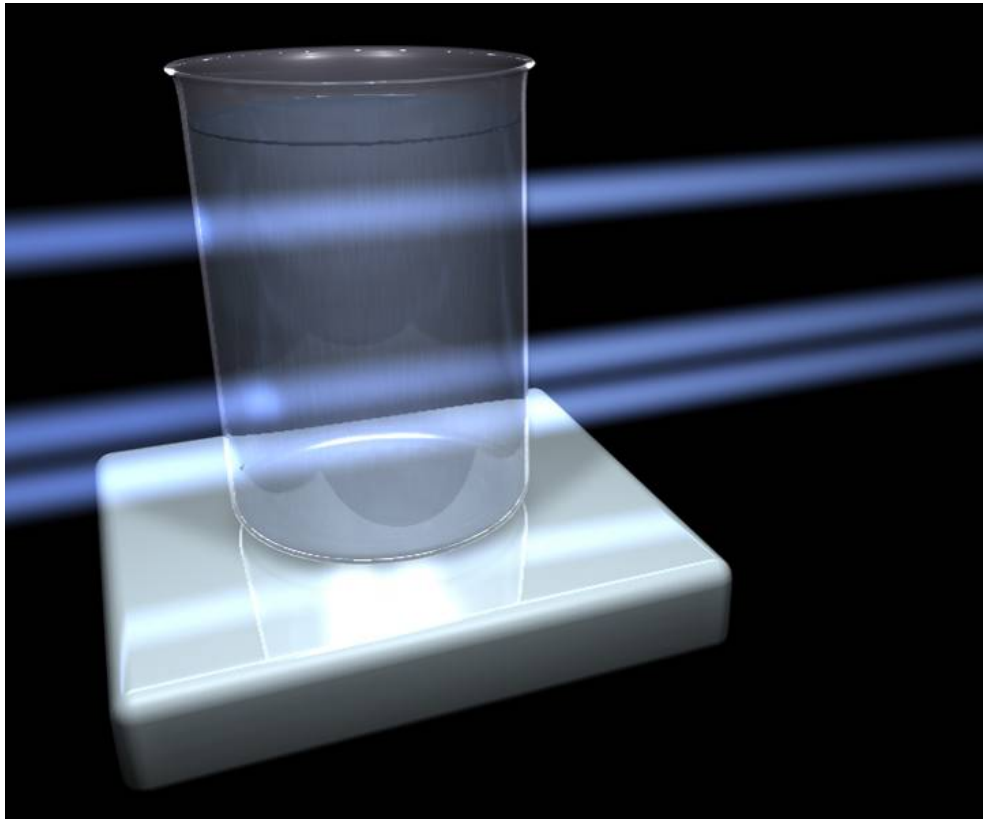
UV Transmittance (UVT)
The ratio of light entering the water to that exiting the water – usually reported for a path length of 1 cm. UVT is often represented as a percentage and is related to the UV absorbance by the following equation:

$$\%UVT = 100 \times 10^{-A}$$

As the UV absorbance increases, the UV transmittance decreases.

Examples:
Municipal Treated Tap Water = 80-95% UVT

Treated Wastewater = 40-65%UVT

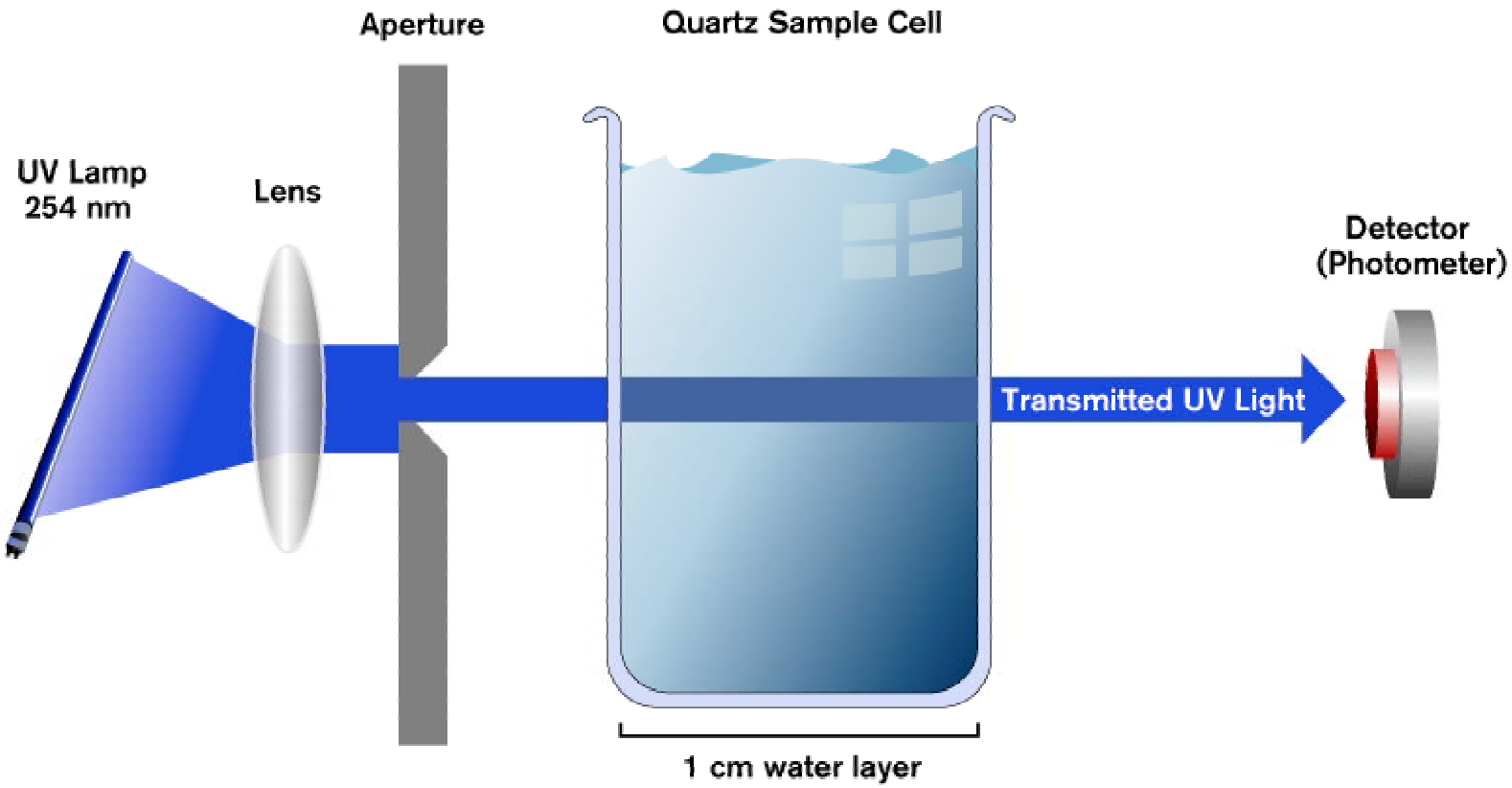


APS

TROJAN UV

UV DOSE WATER QUALITY FACTORS

Measuring UV Transmittance (UVT)

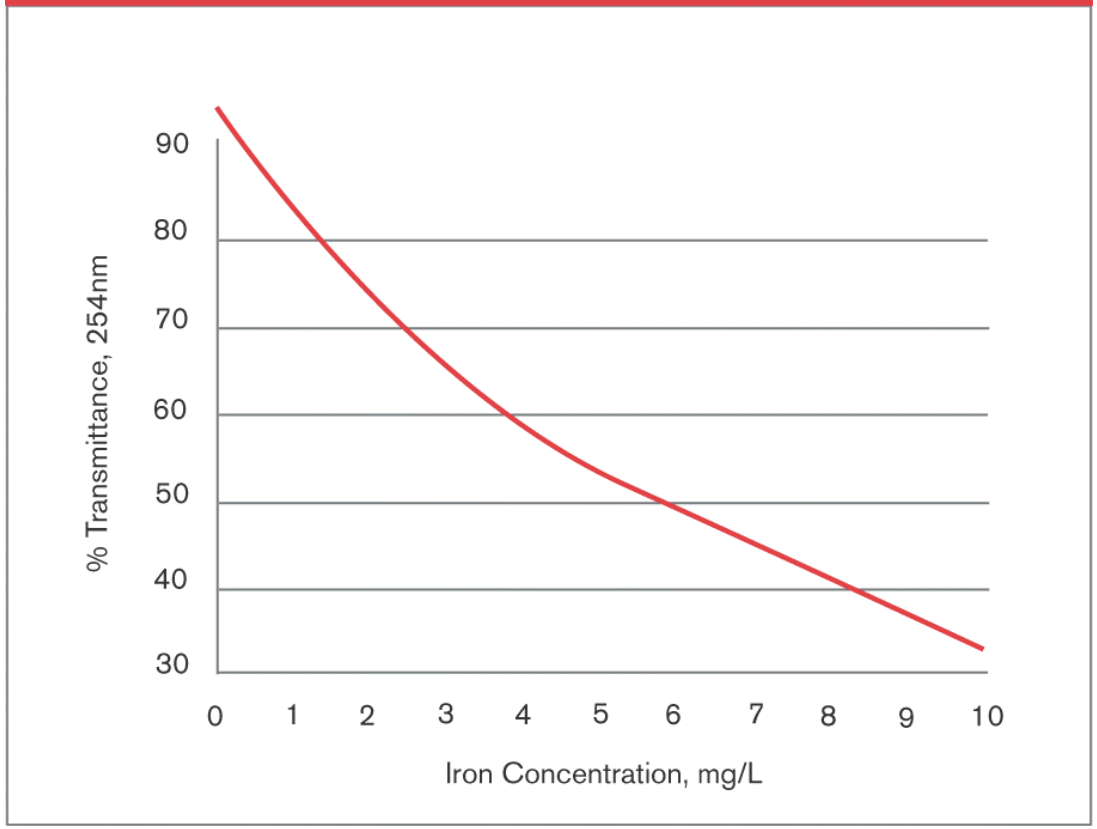


APS

TROJAN UV

UV DOSE WATER QUALITY FACTORS

Effects of Iron



Quartz Sleeve Fouling

Sleeve fouling can affect UV transmittance (%UVT) and disinfection performance. Many variables (water quality, temperature, velocity, chemicals, etc.) can contribute to sleeve fouling

Iron and hardness content in water is often a factor in sleeve fouling

Sleeve cleaning systems offer a means to treat fouling but also have variability (system type, wiper design, wiper frequency, maintenance schedule, water quality, etc). An effective system with an appropriate cleaning schedule is critical

APS

TROJAN UV

UV APPLICATIONS DESIGN CRITERIA

Sizing Considerations

Flow Rate: Design Peak and Average

Water Quality: UVT, Turbidity, Iron, Hardness, Color

Application: Target Organism, Disinfection Limit

Upstream Treatment Process

Chemicals used during Upstream Treatment Process

UV Design Dose Required

Installation Configuration: Available footprint and headloss

Redundancy Requirements

UV DESIGN CRITERIA IMPACT OF UV TRANSMITTANCE

95% UVT →

90% UVT →

Typical UV Transmission Values

Treatment Process	Typical UV Transmission
Filtered Surface Water	75% - 95%
Unfiltered Surface Water	70% - 95%
Groundwater	80% - 95%
Membrane Filtration	> 95%
R.O. Permeate	> 95%

UV DESIGN – WHAT IF THE UVT IS TOO LOW?

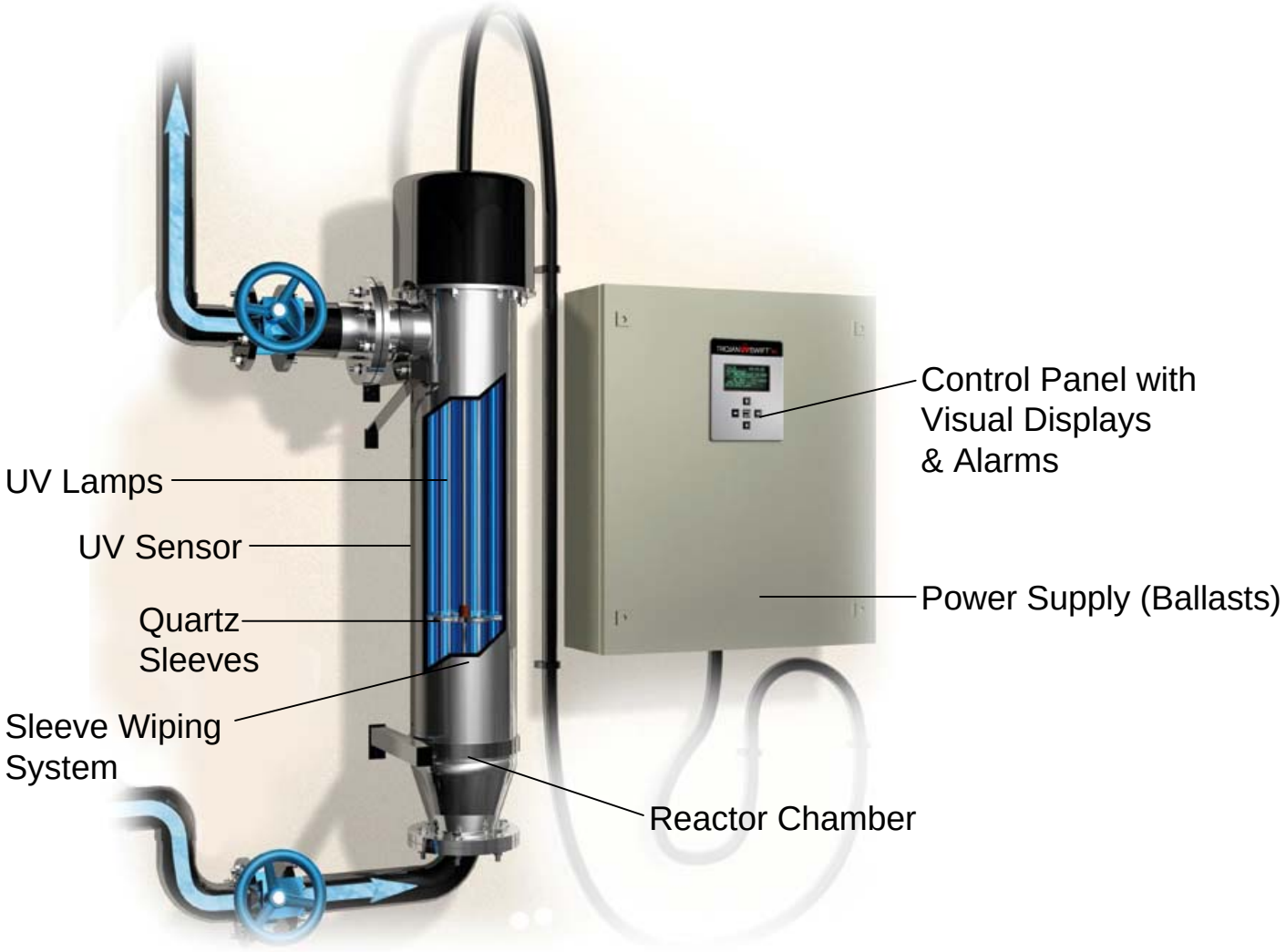
- If the UVT is too low due to organics:
  - An activated carbon pre-filter will usually remove sufficient organics to increase UVT to acceptable levels
    - Recommend that applicability of Activated Carbon be confirmed through sampling/trials
  - An organic compound removal system or further pre-treatment may be required on water with very low UVT due to organics
  - The manufacturer will typically test any water sample for:
    - Pre-filtration UVT
    - Post Filtration UVT
    - Post Activated Carbon UVT
    - Iron
    - Hardness

VARIOUS UV SYSTEMS

APS

TROJAN UV

UV SYSTEM KEY COMPONENTS



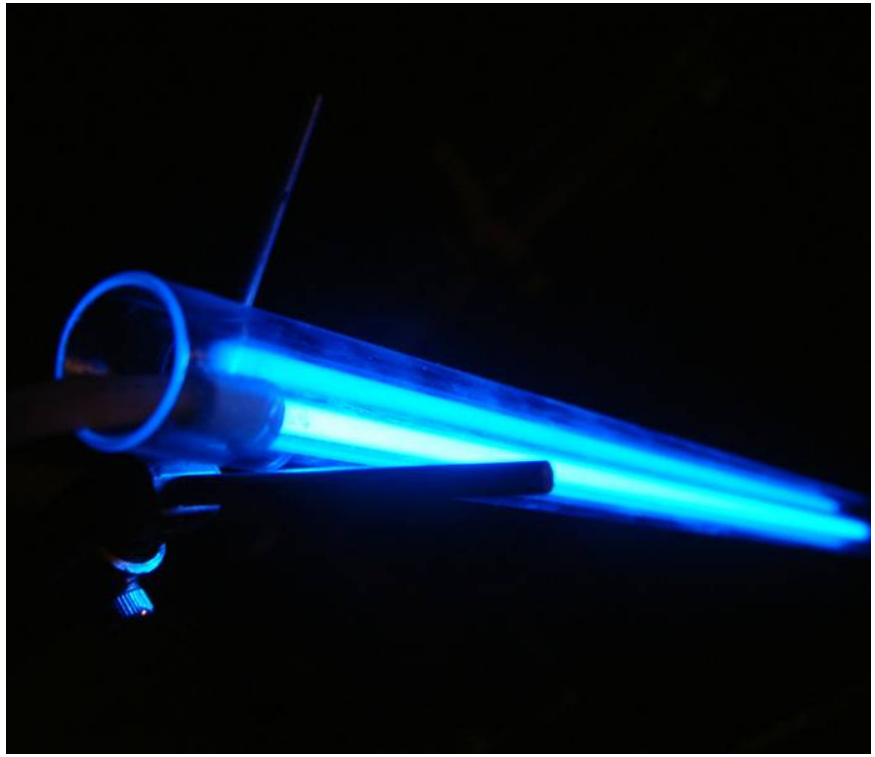
APS

TROJAN UV

UV LAMPS DIFFERENT TYPES

There are three distinct types of UV lamps

These are characterized by the mercury vapor pressure inside the lamp, and the relative UV energy they produce:



Low-Pressure, Low-Output (LPLO)

Used in small systems; limited UV energy

Life: 8,000 to 12,000 hours

Low-Pressure, High-Output (LPHO)

High output allows greater doses from compact systems; this category includes amalgam lamps

Life: 8,000 to 12,000 hours

Requires 1/4 to 1/6 the number of lamps compared to other low-pressure designs

Variable Output

Medium-Pressure, High-Output (MPHO)

Extremely high UV output; capable of treating significant flow volumes and lower quality water

Life: 4,000 to 8,000 hours

Variable Output

APS

TROJAN UV

UV INTENSITY SENSOR / MONITOR

The sensor continually monitors the UV intensity to ensure proper disinfection and goes into alarm if the conditions fall below the operating range

APS

TROJAN UV

UV CONTROL PANEL USER INTERFACE

- Generally, the interface includes a minimum of:
  - Elapsed time meter tells the user how long the lamp has been in service.
  - Audio and visual alarms let the customer know if there is a problem.
  - Service reminders lets the customer know when the lamp needs to be changed or maintenance is required.

APS

TROJAN UV

UV SLEEVE CLEANING SYSTEMS

- Off-Line Chemical Cleaning (OCC)
  - UV Reactor must be shut down.
  - UV sleeves must be removed from the reactor and manually wiped with an approved cleaning chemical
- On-Line Mechanical Cleaning (OMC)
  - UV Reactor stays in operation
  - System provided with wiper canister seals or brushes that provide a mechanical scraping action.
  - Manual chemical cleaning will still be required periodically per the OCC method. Frequency will depend on the type of fouling encountered.
- On-Line Mechanical-Chemical Cleaning (OMCC)
  - UV Reactor stays in operation
  - System provided with wiper canisters containing a cleaning agent. These cleaning mechanisms provide both mechanical scraping action and chemical cleaning

UV SYSTEM OPERATION

- Varies based on
  - UV Manufacture
  - UV Reactor Configuration
  - Dose Monitoring Strategy
- Automatic or Manual
  - On/Off
  - Dosing Levels
  - Chemical and Mechanical Cleaning

APS

TROJAN UV

UV OPERATION – RECOMMENDED ACTIONS

- Daily
  - Overall visual inspection
  - Confirm system control mode
  - Check Control Panel for status of system components and alarm status and history – Display, Lights, Gauges, etc.
  - Verify all on-line analyzers, flow meters and data recording equipment are operating normally
  - Review 24 hour monitoring data to confirm system operating within design limits
  - Verify ballast cooling is taking place
- Weekly
  - Initiate manual operation of wipers to verify proper operation
- Monthly
  - Check lamp run time values. Replace lamps if operating hours exceed design life.
- Semi Annually
  - Check ballasts for unusual noise
  - Check operation of automatic or manual valves

Refer to UV Manufacturer's O&M Manual for all other operational tasks

(eg. Startup, Shutdown, and Winterization Procedures)

APS

TROJAN UV

UV SYSTEM MAINTENANCE

Proper maintenance ensures that UV system meets the intended disinfection requirements.

Poor Maintenance may cause the UV Reactors to operate off-specification for extended periods of time.

Keep inventory of spare parts recommended by UV manufacturer.

UV SAFETY HAZARDS

- UV Light Hazard
  - Use protective face shield & clothing
- Electrical Hazards
  - Follow Lock-out Tag-out procedures!
- Mechanical Hazards
  - Fluid Pressure
  - Hot Surfaces

WARNING

Wear UV Resistant Face Shield!

Unprotected exposure to ultraviolet light can cause sever burns to the eyes and skin. Face shield should be worn as the primary protection against such exposure. Never look directly at the energized lamps unless you are wearing ultraviolet resistant face shield or glasses (for short-term exposure)

WARNING

Electrical Hazard!

Because of the potential hazard from this power source it is prudent to use LOCK OUT procedures and TAG all sources of power before performing any maintenance, cleaning or repairs on any piece of equipment. The power sources may include electrical, hydraulic, or stored energy. Refer to the general lock out and tag procedures in this manual.

WARNING

HOT SURFACE!

ALLOW ELECTRONIC BALLAST AND LAMPS TO COOL BEFORE HANDLING.

ULTRAVIOLET LAMPS BECOME HOT DURING OPERATION. HOT LAMPS CAN CAUSE SERIOUS BURNS. PRIOR TO REMOVING THE LAMPS, ALLOW LAMPS TO COOL FOR A MINIMUM OF 5 MINUTES. THIS PREVENTS BURNS AND DAMAGE TO THE LAMP.

THE SURFACE OF THE REACTOR CHAMBER CAN BECOME HOT DURING NORMAL OPERATION. TOUCHING THE UNIT WHILE IT IS OPERATING CAN CAUSE BURNS. DO NO TOUCH, OR ALLOW ANY MATERIALS TO COME IN CONTACT WITH THE REACTOR CHAMBER WHILE THE SYSTEM IS OPERATION.

Note: Refer to O&M Manual for detailed information about system safety

APS

TROJAN UV

UV RECOMMENDED MAINTENANCE ACTIONS

- Monthly
  - Check Cleaning Efficiency
    - Record UV Intensity Sensor Reading
    - Extract 1 sleeve per reactor for inspection
      - If fouling is observed, check remaining sleeves and UV intensity sensor window
      - Manually clean sleeve(s) and UV sensor window
    - Record UV Intensity Sensor Reading after cleaning and compare to original reading
- Semi-Annually
  - Check Wiper Cleaning Fluid if equipped
    - Replenish solution if reservoir level is low.
    - Drain and Replace solution if solution is discolored
- Annually
  - Drain, clean and inspect inside of reactor chamber
  - Calibrate Reference UV Sensor
  - Replace o-rings, wiper seals, brushes, etc as recommended by manufacturer

APS

TROJAN UV

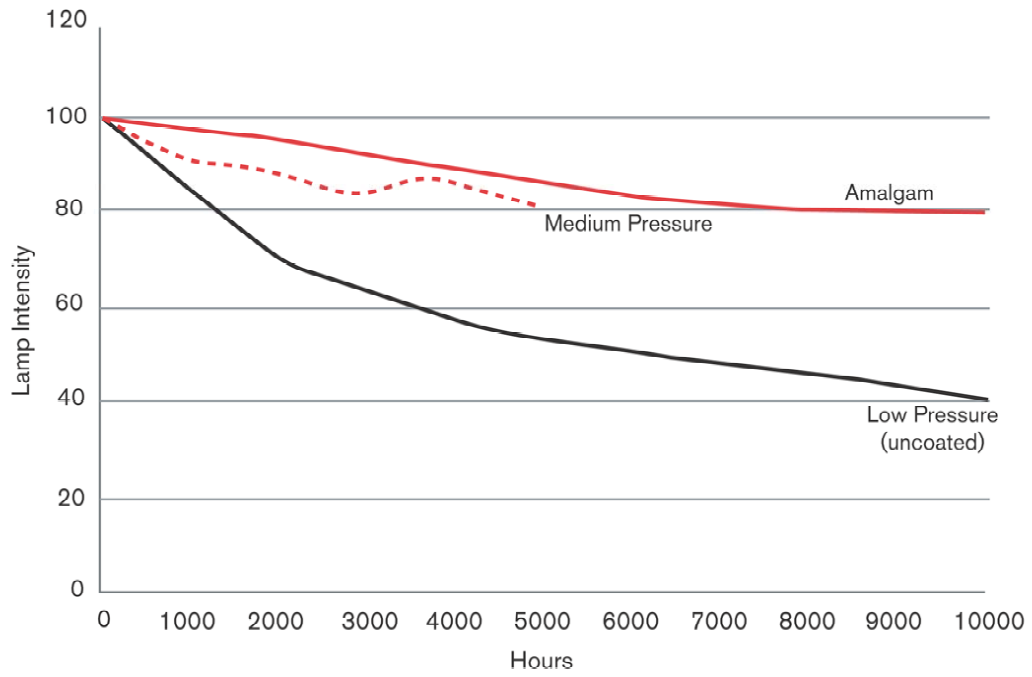
UV SYSTEM MAINTENANCE REQUIREMENTS

- Lamp Replacement
  - Depends on Lamp Type and Manufacturer's recommendation
  - Lamp has failed or has been broken
  - UV lamp output decreases over time
  - Low UV intensity or dose signal cannot be corrected by sleeve and sensor cleaning or water quality improvement
- Lamps should be handled using clean dry cotton, powder free latex, or vinyl gloves.
  - Fingerprints can inhibit proper operation
- Do not install a lamp if it is wet or dirty. Wet lamps must be dried thoroughly. Dirty lamps should be cleaned according to manufacturers recommendation if not discarded.

APS

UV LAMPS LAMP AGING

Sample UV Lamp Degradation Curves



- Aging reduces the transmission of UV energy through the quartz, and also depletes the available mercury in the lamp
- Different types and brands of lamps degrade at varying rates
- System sizing should be based on UV dose at the *end of lamp life (EOLL)*
- End of lamp life output should be validated to ensure proper factors are used for design

APS

TROJAN UV

UV SYSTEM MAINTENANCE REQUIREMENTS

- Sleeve Replacement
  - Replace when damaged, cracked, or irreversible fouling significantly decreases UV intensity of an acceptable lamp.
  - Abrasion of the sleeve surface during handling or mechanical cleaning may contribute to loss of UVT
    - Reduced UVT is reflected in the UV sensor reading
  - Follow manufacturer's procedure closely as the sleeve can crack and break from over tightening of the compression nuts that hold it in place.
- UV Intensity Sensor Replacement
  - Replace when damaged or UV intensity reading not consistent or reflective of an acceptable lamp and sleeve.
- Replace other parts according to manufacturer's recommended frequency and procedure.

UV MAINTENANCE
SLEEVE FOULING & UV SENSOR SURFACE / WINDOW FOULING

- The frequency of cleaning is site specific.
  - An appropriate frequency can be determined based on the rate of fouling which can be assessed by monitoring over time the UV sensor measurement or validated dose.
  - Cleaning Frequency should be increased or decreased based on the amount of fouling left on the sleeves as determined from the sleeve inspections and the loss of UV intensity.
- Compare sleeves against a white lint free cloth next to a new sleeve to determine extent of fouling
  - Sometimes, it is necessary to allow the sleeve to dry in order to see the extent of fouling.
- Sleeves should be handled with cotton or powder free latex gloves

UV MAINTENANCE
SLEEVE FOULING & UV SENSOR SURFACE / WINDOW FOULING

- UV reactor must be drained for sleeve inspection
- All sleeves in the system will foul at the same rate and should be cleaned at the same time. UV sensor surface or window should also be cleaned any time the sleeves are cleaned.
- Clean with a lint free non abrasive cloth and a solution recommended by the UV manufacturer
  - Do not use abrasives or pads as they will scratch sleeve
  - Inside of sleeve must be dry before re-installation – water or chemicals will cause coatings on inside of sleeve
    - Sleeve can be rinsed with isopropyl alcohol for drying
  - Rinse outside of sleeves and sensor with water after cleaning to remove excess chemical

UV MAINTENANCE
SLEEVE FOULING & UV SENSOR SURFACE / WINDOW FOULING

- If equipped with a mechanical or mechanical chemical cleaning system, streaks may indicate wiper material is worn, damaged or misaligned.
  - If discovered, wiper system should be inspected.
- If equipped with a mechanical chemical cleaning system, the cleaning solution reservoir should be replaced if discolored or if the system is not cleaning the sleeves effectively.
  - For some systems, the sensor window does not have a mechanical or mechanical chemical cleaning system. If this is the case and a low UV intensity signal is encountered, the sensor should be cleaned.

Even if system is equipped with a mechanical cleaning system, manual chemical cleaning will still be required.

Clean Sleeve

Fouled Sleeve

Mechanical Wiper (without chemicals)

Mechanical / Chemical Cleaning

APS

TROJAN UV

UV MAINTENANCE - RECOMMENDED SPARE PARTS

- UV Lamps
  - 10 percent with a minimum of 2 lamps
- Sleeves
  - 5 percent with a minimum of 1 sleeve
- O-Ring Seals
  - 5 percent with a minimum of two seals
- Mechanical Cleaning Systems
  - 5 percent with a minimum of two wipers
  - 2 percent with a minimum of 1 wiper drive mechanism
- Ballasts
  - 5 percent with a minimum of 1 unit
- Duty UV Sensor
  - Number based on operating experience and quantity installed

APS

TROJAN UV

UV TROUBLESHOOTING – TYPES OF ALARMS

- Minor Alarms
  - UV Reactor remains ON
  - Attention required but not immediately – Disinfection likely not affected
  - Examples:
    - End of Lamp Life Hours
    - Wiper Fault
- Major Alarms
  - UV Reactor remains ON – Usually increases to 100% Output
  - Attention required – Disinfection potentially compromised
  - Examples:
    - Low UV Intensity / Dose
    - Lamp Failure
    - Ballast Failure
    - Communication Failure
- Critical Alarms
  - UV Reactor turns off – typically restarts automatically when conditions permit
  - Attention required ASAP – Disinfection compromised
  - Examples:
    - High Temperature
    - Reactor no completely full

UV TROUBLESHOOTING - LAMPS

- Lamp Alarm
  - Respective lamp has failed
    - Replace with new lamp
  - Lamp power cable from ballast faulty or disconnected
    - Remove and replace faulty power cable between ballast and lamp
  - Damaged lamp ballast
    - Replace lamp ballast
- End of Lamp Life Hours Alarm
  - Lamps have reached their End of Service Life (EOL)
    - Replace all lamps in the system and **reset lamp hours to zero**

UV TROUBLESHOOTING – BALLASTS & HIGH TEMPERATURE

- Ballast Alarm
  - Faulty ballast power supply
    - Ensure proper power supply
  - Faulty Ballast
    - Remove and replace faulty ballast
- Reactor High Temperature Alarm
  - Chamber has reached its high temperature limit due to reactor operating partially full or empty
    - Ensure reactor is full of water
    - If a minimum flow through reactor is required, ensure it is available
  - Typically shuts the system down until temperature has lowered to an acceptable level and alarm is deactivated
- Wiper System Alarm
  - Loss of communication
  - Wiping Cycle not completed properly

UV TROUBLESHOOTING – LOW UV INTENSITY

- Low UV Intensity Alarm
  - UV intensity has dropped below the alarm set point due to:
    - Lamp failure
      - Replace lamps
    - Lamp aging
      - Replace lamps
    - Sleeves fouled
      - Clean sleeves
      - Check wiping system
    - Worn sleeve wipers
      - Replace sleeve wipers
    - UV sensor window fouled/condensation covered
      - Clean UV sensor window
    - Low UV Transmittance
      - Check source water for UVT
    - Missing UV intensity signal
      - Ensure UV sensor is installed and connected to panel

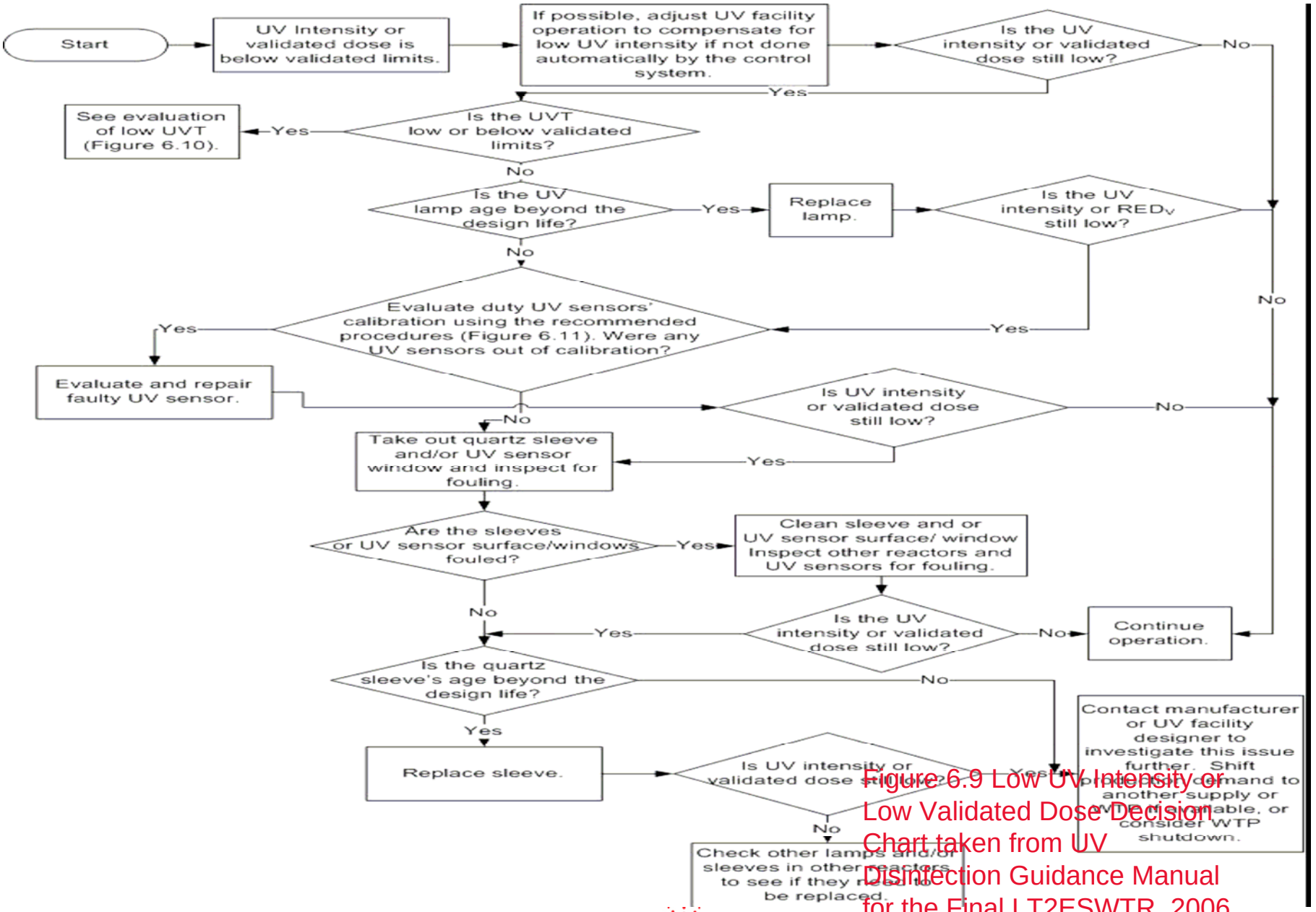


Figure 6.9 Low UV Intensity or Low Validated Dose Decision Chart taken from UV Disinfection Guidance Manual for the Final LT2ESWTR, 2006

APS

TROJAN UV

SUMMARY

- **Introduction to UV Light**
- **UV Dose**
- **Design Criteria**
- **Key Components**
- **Operation**
- **Maintenance**
- **Troubleshooting**

APS

TROJAN UV

QUESTIONS

Atlantic Purification Systems
Robert Gillis
10 Ferguson Road
Dartmouth, Nova Scotia
B2Y 3Z5
Ph: 902-469-2806
Fax: 902-463-3529
E-Mail: robert@aps.ns.ca