

**ULTRAVIOLET DISINFECTION OF SEWAGE
TREATMENT PLANT EFFLUENT
A PILOT PROJECT**

FINAL REPORT

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Introduction and Description of Project

There are presently ten sewage treatment plants located in the watershed of the Peconic Estuary, six of which discharge directly to surface waters. While sources of nitrogen from these sewage treatment plants have had much discussion recently, control of coliform bacteria (and the pathogenic organisms they indicate) is another important aspect of these sewage treatment plants. The present means of disinfection used by all of these sewage treatment plants is chlorination of the effluent. While chlorination provides for disinfection to protect public health, there is a negative environmental impact from chlorine and chlorinated compounds entering marine surface waters. The Peconic Estuary Program (PEP) Action Plan identifies the sewage treatment plants in the Peconic Estuary watershed as point sources of pollution to the estuary.

An alternate method of disinfection of sewage treatment plant effluent is through the use of ultraviolet (UV) light. UV light adds nothing to the water column and is effective as a germicide because of photochemical damage to RNA and DNA within the cells of an organism. Disinfection of sewage treatment plant effluent by UV has the potential to not only protect public health, but to also improve water quality and habitat in the Peconic Estuary by eliminating the harmful environmental side effects of chlorination.

This project performed an on-site pilot study of the effectiveness of UV sterilization for a sewage treatment facility in the Peconic Estuary utilizing a closed chamber ultraviolet disinfection system. The sewage treatment facility

owned and operated by the Shelter Island Heights Property Owners Corporation (SIHPOC) is the site of this project. Effluent was drawn offline from the treatment facility (before chlorination), and passed through the UV sterilization system and then analyzed for effectiveness of sterilization. This pilot study was carried out over a range of different flow volumes typically experienced by the treatment facility. The suitability of UV sterilization as a cost-effective treatment method that can improve protection of the environment for the Peconic Estuary is assessed.

Project Need

As pointed out in the PEP Action Plan under the heading of pollution sources in the Peconic Estuary, point sources include the ten sewage treatment plants within the Estuary watershed, six of which discharge directly to surface waters. Recommendation II-2.A.2 Sewage Treatment Plants - east of Flanders Bay, states that pollution from other sewage treatment plants in the study area should be controlled such that existing water quality in the surface waters east of Flanders Bay is maintained. This is the priority problem that this project addresses. If the environmental problems associated with chlorinated effluent are to be addressed in the Peconic Estuary System, then a pilot-scale project to look at the effectiveness of utilizing UV sterilization is appropriate. It is also appropriate to utilize a small-scale treatment facility for this project. The SIHPOC has offered, and given their support, to utilizing their treatment facility on Shelter Island as a platform for this pilot project. Further, the SIHPOC is very

much interested in, and willing to participate in this project, and is very interested in learning about alternative cost-effective treatment methods that can improve and protect water quality in the Peconic System. Therefore, utilization of the SIHPOC treatment facility is fully justified as a proper demonstration site for this project.

Infilco Degremont, Incorporated (IDI), an international company that designs and operates water and wastewater treatment facilities, has been working with numerous sewage treatment plants on the conversion from using chlorination for disinfecting effluent to the use of ultraviolet disinfection systems. IDI has numerous UV installations in Upstate New York and other states as well. However, the use of UV for the disinfection of sewage treatment plant effluent has not been widely used on Long Island. IDI offered the use of a self-contained IDI Aquaray closed chamber type ultraviolet disinfection system for use in this project. The unit was leased for a six-week period and IDI donated the unit for a six-week period so that typical summer flows, as well as typical winter flows were part of this project. Additionally, the Shelter Island Heights Property Owners Corporation is extremely interested in this project and has offered the use of their treatment facility as a platform for this pilot project.

The IDI Aquaray unit that was used is essentially a small self-contained unit with 2 sets of UV lamps mounted in a stainless steel chamber. The installation draws unchlorinated effluent from the existing treatment plant's chamber and pumps it through a small ultraviolet disinfection unit. The water

leaving the UV was returned to the decant chamber where it combined with the rest of the plant flow for chlorination and disposal in the current manner. To determine the effectiveness of the ultraviolet system, samples were taken of the influent and effluent of the pilot unit twice a week, and monitored for both Fecal and Total Coliform. Total suspended solids were also monitored. Sampling was carried out by project personnel. Analysis of samples was performed by the Suffolk County Department of Health Services Laboratory. The regular SPDES permit sampling for the treatment system was used as a basis of comparison.

Results

Sampling and operation of the UV unit occurred during two different six-week periods: 8/4/97 through 9/25/97; 1/12/98 through 2/18/98. These periods reflect high flow conditions when the STP is at capacity during summer and low flows when the STP is way below capacity during winter. The area served by the STP is primarily a summer tourist/seasonal home community, hence vast differences in flows.

The UV system was set up and operated according to Infilco Degremont's operation manual, "Ultraviolet Disinfection System Aquaray OCV-16S Open Channel Vertical Pilot Unit". A copy of this manual is attached as Appendix A.

Sampling and analysis were performed as per the Suffolk County Department of Health Services EPA-approved QAPP. The QAPP is on file with the Department of Health Services Analytical Lab.

Data collected during the two time periods that the pilot unit was operated are presented in Table 1. UV-1 samples were taken on the inlet side of the UV unit and UV-2 samples were taken on the effluent side of the unit, after exposure to the UV lamps.

The SPDES permit requirements for the Shelter Island Heights STP are given in Table 2. Monitoring results from the STP chlorinated effluent for SPDES compliance are presented in Table 3. The STP typically samples only monthly for bacteria.

Values for flow rates through the UV unit are also given in Table 1. Flow was regulated via a valve on the inlet side of the unit and calculated by depth of water spilling over a V-notch weir located inside the UV-unit.

Values for total suspended solids are also given in Table 1. However, there were problems associated with running TSS for a period of time at the County Lab. As a consequence, most of the TSS sample results for this project were invalid, as were other TSS samples run by the Lab. Consequently, we only have 4 values for this project.

Discussion

The values for UV-2 for both total and fecal coliforms (after exposure to U-V light) are relatively high for most of the August sampling events and for many of the September sampling events. Even though there is a significant decrease in both total and fecal coliforms after exposure to UV, the effluent values of the pilot unit are greater during this time period than the chlorinated

effluent. The results are also greater than what would be expected from UV disinfection.

There was only one instance when the UV effluent exceeded the SPDES daily maximums - 8/18/97 for fecal coliforms. However, the geometric mean for the UV samples during the month of August exceeds the SPDES 30-day geometric mean for both total and fecal coliforms. Results in September were better than in August. There were no instances of levels exceeding the daily maximum. Additionally, the geometric mean for the month of September samples was below the SPDES requirements for both total and fecal coliforms.

The unit performed extremely well during the January/February 1998 period with all samples for both total and fecal coliforms registering less than 20 mpn/100ml.

The high levels during August and September may have been due to the need to "fine tune" the UV unit as well as possibly the levels of total suspended solids in the effluent flowing through the unit.

The dosage rate for the UV unit is determined by the flow rate and the UV transmittance. UV transmittance is a function of TSS. For most of the August/September 1997 period, the flow rate was 34.2 gpm. When the flow rate was adjusted downward to 27.5 gpm at mid-September improvement in disinfection was realized, but levels were still somewhat high. The first two samples for the project (8/4 and 8/7) were also at 27.5, but we are still determining how best to interact the UV unit with the STP treatment process.

TSS levels at the time of sampling still remain an unanswered factor in UV effectiveness. Because of the problems mentioned above with TSS samples, only four TSS sample results were viable and do not give a clear or complete picture of TSS in the effluent. Infilco Degremont suggests TSS of 30 mg/L or less for effective UV treatment. The samples for 9/2/97 had an associated TSS level of 80 mg/L, well above the recommended amount. Also, it is known that during the sampling event of 8/25/97, solids were pumped from the STP treatment tank into the UV pilot unit and that TSS were probably high.

The procedure that had to be used to pump STP effluent into the UV chamber may have also impacted TSS levels. The STP consists of two tanks that are alternatively dosed, aerated and allowed to settle before final effluent is pumped to the chlorine contact chamber. In order to run the UV unit, a submersible pump was lowered into one or the other tank depending on where in the treatment cycle each tank was. Sampling events were timed, to the extent possible, to try to coordinate with the settling phase of one tank or the other. However, these could not always be timed precisely. In any event, a period of time was allowed for the tank to settle after aeration and before pumping to the UV unit. Further, liquid was allowed to flow through the UV unit for 30-45 minutes after pumping into the unit commenced. It was not possible to pump liquid from the STP just before chlorine contact, into the UV unit. As a result, TSS concentrations were likely highly variable and may have had an impact on results. But, because we do not have the TSS data, this cannot be stated explicitly.

Results from the January/February 1998 sampling consistently show low levels (less than 20 mpn/100 ml) on both total and fecal coliforms. Performance of the UV unit during this period, as evidenced by the mpn results was excellent.

This was probably due to several factors:

- Low flows and higher treatment efficiency for the STP during this time of year
- Probably lower levels of TSS in the liquid flowing through the UV unit, although this cannot be known for sure, but is based on low flow conditions
- A lower rate of flow through the UV unit
- A probable higher dosage based on the above

As another means of getting at the TSS issue, we can also examine the TSS data from the STP SPDES monitoring samples. This is shown in Table 4.

Although the weighted average of the plant's final effluent does not show much difference between August/September 1997 and January/February 1998, the influent levels are quite different. Recall that liquid for the UV unit was not able to be pumped from the final STP effluent just before chlorine contact, but was pumped from the treatment tank.

The weighted average of TSS for STP influent was 238 mg/L and 192 mg/L for August 1997 and September 1997 respectively. The weighted average was 61 mg/L and 109 mg/L for January 1998 and February 1998 respectively.

In conclusion, it appears that UV light can be a viable alternative to chlorine as a means of disinfection of STP effluent in the Peconic Estuary, thus eliminating habitat impacts of chlorine residuals. The unit operated at an excellent level of performance during winter low flow conditions. Although the unit did not perform as well during summer peak flow conditions, this may have been due to less than optimum UV dosage. A successful UV treatment plan for a STP would have to refine, address and closely monitor optimum dosage conditions.

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Bernie Jacobson and Hans Schmid, Shelter Island Heights Property Owner's Corp.

Mack Waters, Suffolk County Department of Health Services

Dr. John Kelly, Peconic Estuary Program - Citizen's Advisory Committee

Al Kilb, Shelter Island Highway Department

UV-1 = Before Exposure to UV

TABLE 1.

UV-2 = After Exposure to UV

Date	Station	Total Coliform (MPN/100 ml)	Fecal Coliform (MPN/100 ml)	Total Sus.Sol. (mg/L)	Flow (gpm)
8/4/97	uv-1	>16,000	>16,000		
	uv-2	2,200	1,100		27.5
8/7/97	uv-1	>16,000	>16,000	2	
	uv-2	3,000	300		27.5
8/11/97	uv-1	>1,600,000	>1,600,000		
	uv-2	500	170		34.2
8/14/97	uv-1	>1,600,000	>1,600,000		
	uv-2	1,700	260		34.2
8/18/97	uv-1	>1,600,000	>1,600,000	3	
	uv-2	9,000	9,000		34.2
8/21/97	uv-1	>1,600,000	900,000		
	uv-2	20	20		34.2
8/25/97	uv-1	>1,600,000	>1,600,000		
	uv-2	5,000	130		34.2
8/28/97	uv-1	>1,600,000	>1,600,000		
	uv-2	220	130		34.2
geo.mean	for Aug.	1,013	286		
9/2/97	uv-1	>1,600,000	>1,600,000	80	
	uv-2	5,000	1,400		34.2
9/4/97	uv-1	300,000	300,000		
	uv-2	<20	<20		34.2
9/8/97	uv-1	>1,600,000	>1,600,000		
	uv-2	500	80		34.2
9/11/97	uv-1	>1,600,000	>1,600,000	1	
	uv-2	<20	<20		27.5
9/22/97	uv-1	>1,600,000	>1,600,000		
	uv-2	500	230		27.5
9/25/97	uv-1	500,000	50,000		
	uv-2	1,300	300		27.5
geo.mean	for Sept.	289	119		
1/12/98	uv-1	>160,000	30,000		
	uv-2	<20	<20		27.5
1/14/98	uv-1	500,000	220,000		
	uv-2	<20	<20		27.5
1/20/98	uv-1	300,000	110,000		
	uv-2	<20	<20		27.5
1/21/98	uv-1	50,000	2,100		
	uv-2	<20	<20		27.5
1/26/98	uv-1	1,600,000	110,000		
	uv-2	<20	<20		27.5
1/28/98	uv-1	1,600,000	140,000		
	uv-2	<20	<20		27.5
2/2/98	uv-1	900,000	500,000		
	uv-2	<20	<20		27.5
2/4/98	uv-1	500,000	500,000		
	uv-2	<20	<20		27.5
2/9/98	uv-1	300,000	300,000		
	uv-2	<20	<20		27.5
2/11/98	uv-1	130,000	11,000		
	uv-2	<20	<20		27.5
2/17/98	uv-1	300,000	240,000		
	uv-2	<20	<20		27.5
2/18/98	uv-1	110,000	24,000		
	uv-2	<20	<20		27.5

Table 2.

Shelter Island Heights S.T.P.

SPDES Permit Requirements

Total Coliforms:

Monthly Median (geometric mean)
700 mpn/100ml

Fecal Coliforms:

30-day geometric mean	200 mpn/100ml
7-day geometric mean	400 mpn/100ml
Daily Maximum	2400 mpn/100ml

Reference: Paresh Shah NYSDEC

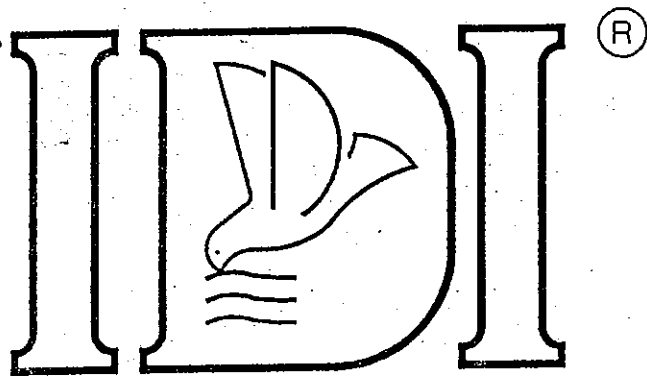
Table 3
SPDES Monitoring Results - Shelter Island Heights STP
Bacteria Sampling

	Total Coliform (mpn/100ml)	Fecal Coliform (mpn/100ml)
8/20/97	1600	2
9/25/97	2	<2
1/20/98	14	4
2/22/98	30	2

Table 4
SPDES Monitoring Results - Shelter Island Heights STP
Total Suspended Solids Sampling

Date	Influent mg/L	Effluent mg/L
8/20/97	180	3
8/25/97	280	14
Weighted Ave. month	236	9.1
9/21/97	200	5
9/25/97	180	3
Weighted Ave. month	192	4.2
1/22/98	51	8
1/26/98	71	6
Weighted Ave. month	60.6	7.0
2/22/98	190	11
2/25/98	44	9
Weighted Ave. month	109.4	9.9

**Ultraviolet Disinfection System
AQUARAY® OCV-16S Open Channel
Vertical Pilot Unit**



**Infilco
Degremont
Inc**

Infilco Degremont Inc

VERTICAL OPEN CHANNEL PILOT PLANT EQUIPMENT DESCRIPTION

OPERATING PROTOCOL AND OPERATING INSTRUCTIONS

I. OPERATING PROTOCOL:

The Pilot Plant is designed to simulate a full scale open channel disinfection system both in terms of operating performance and maintenance requirements. It consists of a self contained open channel with an adjustable level control weir to maintain proper lamp immersion, 16 ultraviolet lamps each having a 14" arc length, an inlet box with "vee" notch weir, air scrub compressor, and a fully equipped control panel.

The testing procedure will provide the plant operations staff with much useful data demonstrating:

- Simplicity of operation.
- Ease of maintenance.
- Optimum operating performance in terms of flow per inch of lamp arc.
- A close approximation of cleaning frequency.
- The optimum cleaning material.

Unless a sample of effluent has been received by IDI for testing of the waters ability to transmit ultraviolet light, the following assumptions will be made:

1. The ultraviolet transmission efficiency of the water is 65% (T10).

T836.500-1
5/12/95

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2. The BOD is 30 mg/L or less.
3. The total suspended solids is 30 mg/L or less.
4. The required effluent standard is to have less than 200 mpn/100 mL (Fecal Coliforms).

Based on the foregoing, the plant will initially be set up to operate at a flow equivalent to the average daily flow.

The pilot plant will then be allowed to operate continually for a period time with regular readings being taken of the following parameters:

- Date and Time
- Flow in gpm
- Influent BOD
- Influent SS
- Influent Fecal Coliform
- Effluent Fecal Coliform
- UV intensity
- Operating voltage
- Elapsed time

The system should continue to operate until the final effluent quality deteriorates to the point where final effluent fecal coliform is consistently outside the acceptable range. The date and operating period should then be recorded.

At this stage the system should be fully cleaned, and disinfected and the test repeated to check the operating period. In the event that the period is duplicated, within acceptable limits, the cleaning frequency can be estimated. If the performance is poor or the operating period unacceptably short the flow rate should be reduced and the test repeated until acceptable figures are obtained.

Having completed the testing at the equivalent of average flow, tests can now be carried out at the equivalent of the peak flow condition.

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5/12/95

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Flow rates can be checked using the "vee" notch weir and gauge provided or an in-line flowmeter, if available.

Should a study of the effluent UV transmission reveal a poor quality the initial set up will be designed to suit the measured UV transmission.

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5/12/95

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II. HOUSEKEEPING:

As with a regular treatment facility the channel should be checked frequently for accumulation of solid material or algae growths which may detract from the UV performance by unbalancing the test results.

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III. PRELIMINARY SETUP:

Set the unit in place. A 9'-0" x 1'-6" flat surface is required near the discharge basin. The unit has a 4" threaded inlet (with 4" x 3" reducer) and a 6" flanged outlet. The unit is provided with:

- Submersible Pump
- 10 ft. Pump Discharge Hose (3" diameter)
- Inlet Valve

Bolt the control panel to the channel on the left side of the inlet using the provided bolts.

The unit is provided with an air compressor and hoses. Connect the quick-disconnect to each module and to the compressor air hose. The compressor's power cord should be plugged into the outlet at the left side of the control panel.

The control panel has two cables with connectors. Plug each connector to a UV module. The module closest to the outlet is Module One.

The photocell should be attached to any lamp in Module One. The cable should be routed through the notch in the side of the channel so it doesn't get pinched between the module and channel wall. The photocell then plugs into the connector base on the side of the control panel.

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IV. ELECTRICAL INSTALLATION:

The power supply must be as follows:

- 115 VAC, 20 Amp. for the UV control panel and compressor

CAUTION!!

ONLY A QUALIFIED PERSON
SHOULD ATTEMPT TO
TROUBLESHOOT ELECTRICAL
PROBLEMS.

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5/12/95

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V. UV LAMPS:

The UV lamps are installed prior to shipment. If a lamp fails, proceed as follows:

WARNING!!!

EXPOSURE TO ULTRAVIOLET RADIATION
CAN BURN YOUR EYES AND SKIN.
PROTECT YOUR EYES WITH SAFETY
GOGGLES OR A FACE SHIELD DESIGNED
TO PROVIDE PROTECTION FROM 253.7
NANOMETER WAVELENGTH
ULTRAVIOLET RADIATION.

NOTE

Persons using certain drugs, especially those designed to produce photo-sensitivity, may have problem reactions and should avoid any exposure to ultraviolet radiation.

The UV lamps are wired in series connected pairs. If the cause is a failed UV lamp the indicators will go out in pairs. When two indicators are not lit either or both of the UV lamps may be defective.

Open the module cover, power will be interrupted whenever the cover is open.

Unplug the failed UV lamp and slide it from the quartz jacket (UV lamp indicating display and lamp sockets are numbered).

Substitute the suspect lamp in a working circuit and determine through process of elimination which lamp is defective.

If the UV lamp is defective it must be replaced. Check the lamp for moisture at the time of removal. If the lamp is wet remove the module and inspect the quartz jacket.

T836.500-7
5/12/95

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VI. OPERATION AND MAINTENANCE:

The operating Ultraviolet Disinfection System can be checked for proper function by inspecting the lamp indicators on the remote control panel. Each indicator shows the operation of an individual UV lamp, and is numbered to provide quick identification. If an indicator is out, it indicates that a UV lamp is not working.

The UV intensity monitor indicates the level of ultraviolet intensity in the channel and indicates the need for cleaning quartz jackets, lamp replacement or low transmittance of the water (a minimum UV transmittance of 65% T-10 at 253.7 nm).

Rated flow through the pilot units is 70 gpm. Flow rates can be verified by elevation of the influent in V-notch weir at the inlet. Refer to flow chart.

FLOW CHART 90° V-NOTCH WEIR

<u>Inches</u>	<u>Flow (gpm)</u>
1.3	5
1.8	10
2.1	15
2.3	20
2.6	25
2.8	30
2.9	35
3.1	40
3.3	45
3.4	50
3.7	60
3.9	70

Be sure to adjust downstream weir elevation to achieve full lamp submergence whenever flow rate is changed.

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5/12/95

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VII. ULTRAVIOLET INTENSITY MONITOR:

The UV intensity monitor measures and monitors the ultraviolet energy through the water with a UV selective photocell and an electronic circuit. A meter indication of the UV intensity is provided on the front of the control box. Under normal operating conditions, the UV intensity Meter will read close to 100. The water quality is "SAFE" throughout the range of 100 to 25 on the scale. A green pilot light, indicating the "SAFE" condition, will remain lit while the meter reads in the safe region of the scale. An amber warning light indication "LOW" UV output will light when the meter shows 50% of the original intensity. The chamber may need to be cleaned or lamps may need to be replaced to restore the original UV intensity. A red warning light will signal when the water quality falls below the "SAFE" level and the meter reads below 25 on the scale (25% of original intensity).

In addition to the pilot lights, the UV intensity circuit can also control alarms, solenoid valves, and relays.

T836.500-9
5/12/95

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VIII. CLEANING SYSTEM:

In the event the UV intensity drops, the module can be removed from the channel and the jackets cleaned manually with ammonia and Scotch Bright.

The modules may also be cleaned in-place with citric acid and utilizing the integral air scrub system:

1. Shut off flow to UV system.
2. Turn on air compressor.
3. Slowly add citric acid to channel. One pound per 20 gallons of volume is recommended as a starting point. You may add more or less as necessary, depending upon the nature of the coating and/or effluent quality.
4. Allow the air compressor to run for 30 minutes.
5. Drain and flush channel.
6. Return the system to operation.

NOTE

It is recommended to run the air scrub system daily to prevent any solids from collecting in the channel. Frequency and run time will vary depending upon effluent conditions.

T836.500-10
5/12/95

**Technical Data Sheet
 Aquaray™ OCV-16S
 Ultra Violet Disinfection
 Pilot Unit**

Description:

A complete ultraviolet disinfection system including influent pump, integral air scrub system, level control, flow measurement weir and safety equipment. The unit is constructed of stainless steel and can be shipped on a flatbed trailer.

Weight:

- 500 lbs (shipping)
- 800 lbs (operating)

Overall Plan Area:

- 1'-8" x 9'-8"

Overall Height:

- 4'-0"

Influent/Effluent Height: (LL)

- 10"

Electrical Requirements:

- 120V, 1 Phase, 30 amp or 240V, split phase 15A
- Influent pump - 1HP
- Air compressor - 1/2HP

Connections:

- Influent: 4" npt pipe
- Effluent: 6" flange
- Tank drain: 1" female NPT

Process Data:

UV Transmission T [10]	Average Nominal Intensity [uW/cm ²]	Dosage uW-sec/cm ²									
		Flow GPM 6.05	Flow GPM 12.4	Flow GPM 21.7	Flow GPM 27.5	Flow GPM 34.2	Flow GPM 41.8	Flow GPM 50.3	Flow GPM 59.7	Flow GPM 70.2	
30	1752	98,839	48,224	27,557	21,745	17,485	14,306	11,888	10,016	8,518	
35	2018	111,817	54,556	31,175	24,600	19,780	16,184	13,449	11,332	9,637	
40	2318	126,394	61,668	35,239	27,807	22,359	18,294	15,202	12,809	10,893	
45	2653	142,877	69,710	39,834	31,433	25,275	20,680	17,185	14,479	12,313	
50	3037	162,005	79,043	45,167	35,641	28,659	23,448	19,486	16,418	13,962	
55	3492	184,147	89,846	51,341	40,512	32,576	26,653	22,149	18,661	15,870	
60	4051	210,472	102,690	58,680	46,304	37,233	30,463	25,315	21,329	18,139	
65	4762	242,270	118,204	67,545	53,299	42,858	35,065	29,140	24,552	20,879	
70	5683	281,326	137,260	78,434	61,892	49,767	40,718	33,837	28,510	24,245	
75	6890	330,838	161,417	92,238	72,784	58,525	47,884	39,793	33,527	28,512	
80	8473	395,644	193,046	110,312	87,046	69,993	57,267	47,590	40,097	34,099	

ID1 ULV-16 Pilot unit (two 8 lamp vertical UV disinfection modules with 14" arc lamps)

Transmission Avg. Intensity* T [10]	6.05 1.5	12.4 2	21.7 2.5	27.5 2.75	34.2 3	41.8 3.25	50.3 3.5	59.7 3.75	70.2 4
30	1.607	48,224	27,557	21,745	17,485	14,306	11,888	10,016	8,518
35	1.818	54,556	31,175	24,600	19,780	16,184	13,449	11,332	9,657
40	2.055	61,668	35,239	27,807	22,359	18,294	15,202	12,809	10,893
45	2.323	69,710	39,834	31,433	25,275	20,680	17,185	14,479	12,313
50	2.634	79,043	45,167	35,641	28,659	23,448	19,486	16,418	13,962
55	2.994	89,846	51,341	40,512	32,576	26,653	22,149	18,661	15,870
60	3.422	102,690	58,680	46,304	37,233	30,463	25,315	21,329	18,139
65	3.939	118,204	67,545	53,299	42,858	35,065	29,140	24,552	20,879
70	4.574	137,260	78,434	61,892	49,767	40,718	33,837	28,510	24,245
75	5.379	161,417	92,238	72,784	58,525	47,884	39,793	33,527	28,512
80	6.433	193,046	110,312	87,046	69,993	57,267	47,598	40,097	34,099

Void volume 16.1 liters/Module
 Actual Retention time 0.9 * Theor. Retention time
 fp 0.9
 ft 0.9

* Avg. nominal intensities were calculated with UVDIS Ver. 3.1
 ** Flow in GPM
 *** inches of head, 90 degree V-notch weir



