Ultraviolet Water Purification

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A number of factors combine to make the ultraviolet method unique as a means of water purification. Ultraviolet radiation is capable of destroying all types of bacteria. In addition, ultraviolet radiation disinfects rapidly without the use of heat or chemical additives which may undesirably alter the composition of water.

One of the several categories of energy is electromagnetic or radiant energy. Radiant energy travels, in the form of waves, in straight line paths and in all directions from its source. The wavelengths range from very long radio waves to very short X-rays.

The most familiar part of the spectrum is a narrow band of wavelengths visible to the human eye. Another band with wavelengths shorter than those of visible light, and not visible to the eye, is the ultraviolet part of the spectrum.

Ultraviolet radiation can cause changes in living matter. The sun's rays cause sunburn. Rays from a welder's torch burn the unprotected eyes of an observer.

The ultraviolet spectrum includes wavelengths from 2000 to 3900 Angstrom units (Å). One unit is one ten billionth of a meter. The 2000 to 3900 Å range may be divided into three segments:

Long-wave ultraviolet - The wavelength range is 3250 to 3900 Å. These rays occur naturally in sunlight. They have little germicidal value.

Middle-wave ultraviolet - The wavelength range is 2950 to 3250 Å, also found in sunlight. Middle-wave UV is best known for its sun-tanning effect; it provides some germicidal action, with sufficient exposure.

Short-wave ultraviolet - The wavelength range is 2000 to 2950 Å. This segment possesses by far the greatest germicidal effectiveness of all ultraviolet wavelengths. It is employed extensively to destroy bacteria, virus, mold, spores, etc., both air- and water-borne.

Short-wave ultraviolet does not occur naturally at the earth's surfaces, because the atmosphere screens out sunlight radiation below 2950 Å. In order to take practical advantage of the germ-killing potential of short-wave ultraviolet, it is necessary to produce this form of radiant energy through the conversion of electrical energy. The conversion of electrical energy to short-wave radiant ultraviolet is accomplished in a mercury vapor lamp.

Germicidal Lamps

The low-pressure variety of mercury vapor lamp, which can be referred to as a germicidal lamp, provides the most efficient source of short-wave ultraviolet energy. Medium and higher pressure types are less efficient in short-wave output, consume more power, and may cause purifier overheating.

Germicidal lamps are made of special quartz glass that will allow 70 to 90 percent of the short ultraviolet rays to pass. Ordinary glass is not transparent to wavelengths below 3200 Å, Fig. 1. The low pressure mercury vapor lamp emits radiation that is predominately at 2537 Å. This is in the region of maximum germicidal effectiveness, Fig. 2.

Fig. 1 Transmission Curve for High Silica Glass

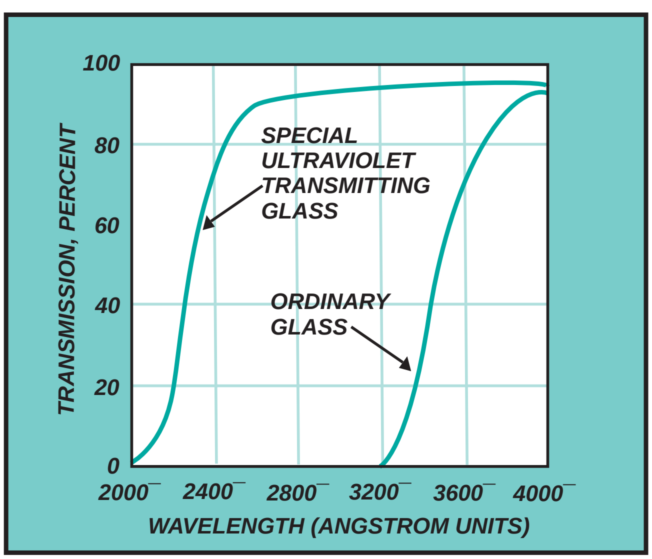
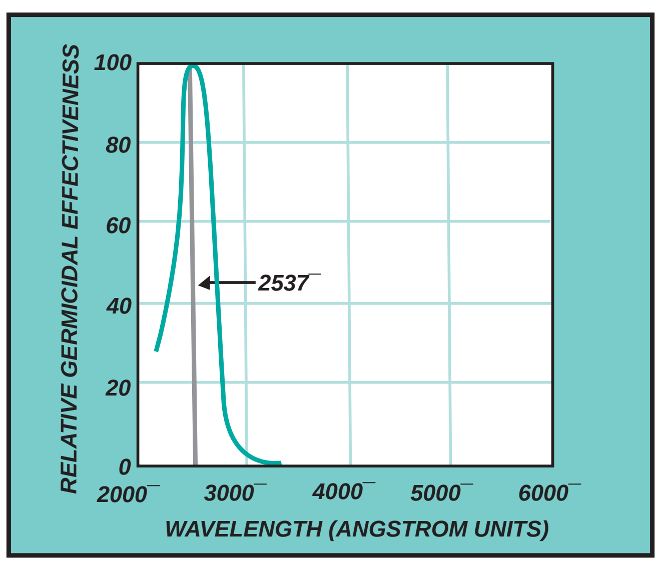


Fig. 2 Germicidal Effectiveness as Related to Wavelength



The germicidal lamp works on the following principle: An electric arc is struck through an inert gas carrier (usually proprietary), in a sealed special glass tube. Heat from the arc causes vaporization of the small amount of mercury contained in the sealed tube. The mercury, when vaporized, becomes ionized and in the electric arc gives off UV radiation.

Required Germicidal Energy

Bacteria withstand considerably more ultraviolet irradiation in water than in dry air. E.coli, for example, requires more UV exposure for their destruction in water than in dry air. In either case, the germicidal radiation must strike a microorganism to destroy it. This implies that the water be clear enough to allow transmission of an adequate quantity of UV energy.

The degree of microbial destruction is a function of both the time and intensity of the radiation to which a given microorganism is exposed. A short exposure time at high intensity is as effective as a long exposure time at low intensity, provided the product of the time and intensity remains the same. This dosage is normally expressed in microwatt-seconds/sq cm.

The dosages required for common bacteria range upward to more than 20,000 microwatt-seconds/sq cm. To allow for less than 100 percent transmission, a purification system should be designed to deliver 2537 Å energy in excess of 30,000 microwatt-seconds/sq cm.

Any turbidity in the water reduces the range of transmission to UV radiation. Water that is naturally turbid, or that has become turbid from corrosion products formed during storage in steel tanks and lines, should be filtered before UV purification.

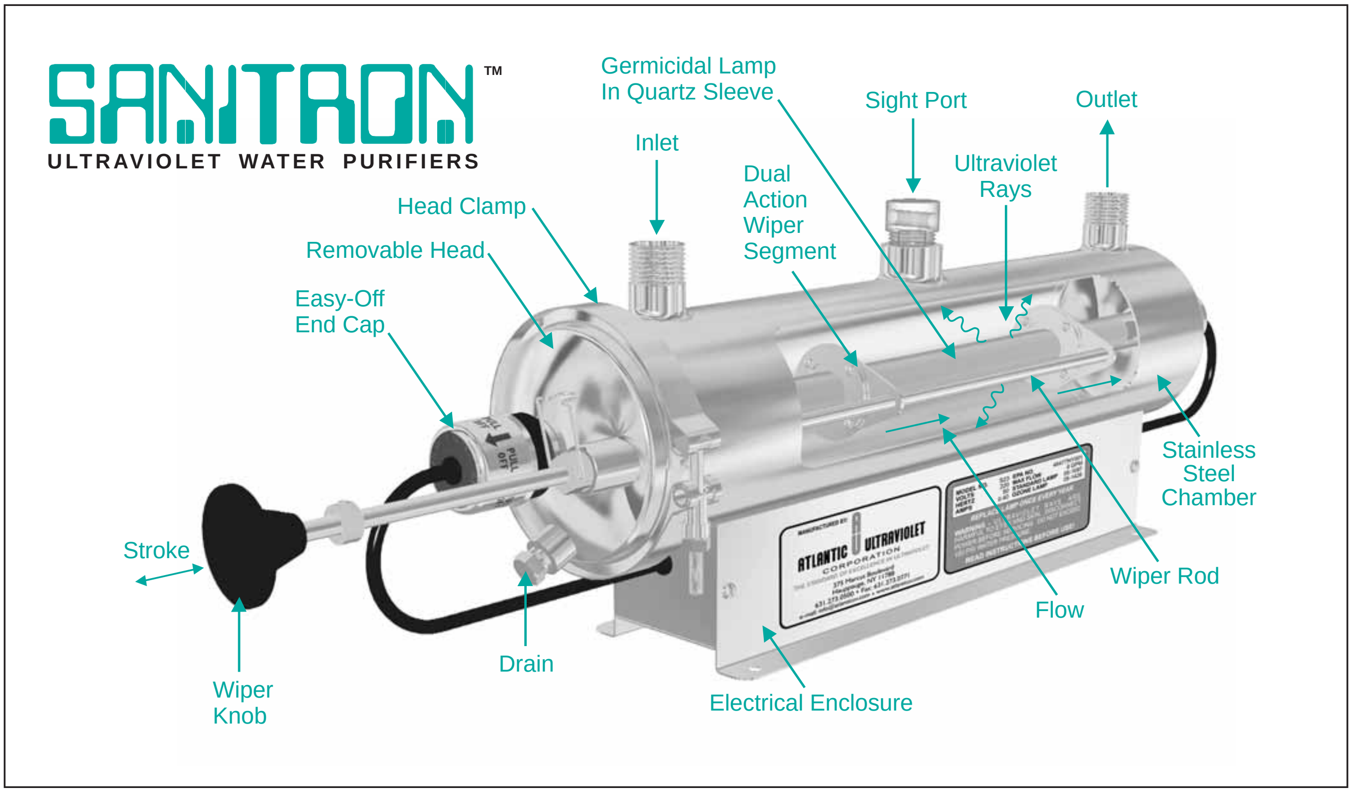
Purifier Design

Several design features bear directly on the dosage delivered:
1. Output of the lamp.
2. Length of the lamp - when the lamp is mounted parallel to the direction of water flow, the exposure time is proportional to the length of the lamp.
3. Design water flow rate - exposure time is inversely related to the linear flow rate.
4. Diameter of the purification chamber - since the water itself absorbs UV energy, the delivered dosage diminishes logarithmically with the distance from the lamp.

A typical UV water purifier is shown in Fig. 3. In operation, water enters the inlet and flows through the annular space between the quartz sleeve (which contains the germicidal lamp) and the outside chamber wall. The irradiated water leaves through the outlet nozzle.

Features to look for:
1. Expandable system - parts should be as uniform and as interchangeable as possible to permit easy expansion later.
2. Sight port - enables visual monitoring of lamp operation; also permits later adaptation to electronic monitor device using the same port.

Fig. 3 Assembly of one type of ultraviolet water purifier.



3. Single lamp per chamber - provides greater safety through more accurate monitoring than does a multi-lamp /single-chamber system.
4. Quartz protection sleeve - cold water moving past an unshielded lamp will reduce the lamp temperature and the radiation yield. A protective quartz sleeve will allow the higher lamp temperature required for optimum output of 2537 Å radiation.
5. Mechanical wiper - for cleaning the sleeve surface without shutdown or disassembly of the unit.
6. Optional accessories - Flow controls, UV monitors, electronic water shut-off valves and alarms, should be available to provide fail-safe operation without operator attendance.
Operating Data:
For tubular lamps of 12 to 48 inches in length, the following data are typical:

Lamp Length	Power Consumption	2537Å Output	Rated Effective Life
12"	10 w	3.1 w	7500 hours
18"	17 w	5.8 w	7500 hours
36"	39 w	13.8 w	7500 hours
48"	50 w	19.3 w	7500 hours

A single lamp purifier can be designed to handle any flow rate up to approximately 2400 gph. By multiplying purifier units, in series and in parallel, the higher flow rates are obtained.

Applications:

The unique advantage of the UV method of sterilization of water is that nothing is added to the water. When chemical methods of treatment are used there may be handling problems, taste and odor problems, and undesirable chemical reactions with substances present in the water. This difference is most significant when producing water for drinking or swimming, processing foods and bottled beverages, manufacturing cosmetics or pharmaceuticals, use in hospitals and research institutions, and tertiary treatment of municipal or industrial wastewater.
The versatility of UV purification includes:

1. UV purification produces germ-free potable water for home, institutional and municipal use.
   - for application to water wells; bacterial contamination of wells is unpredictable and may occur from seepage of surface water or sewage.
   - for installation on outlet side of water cisterns; most cisterns foster the proliferation of bacteria in untreated water.
   - for swimming pools; to control bacteria, algae and slime formation. It avoids the undesirable effects of heavily chlorinated swimming pool water by allowing substantial reduction of the use of chlorine.
2. It provides bacteria-free food process water without the use of germicides, oxidants, algaecides or chemical precipitants; particularly applicable where chlorine adversely affects flavor.
   - for the brewery, winery, soft drink, and water bottling industries, where biological purity of the water must be absolutely maintained in order to insure product quality.
   - for safeguarding against spoilage of dairy products, e.g., cottage cheese and butter; certain psycrophilic bacteria are resistant to chlorine treatment.
   - for sterile washwater; to guard against waterborne bacteria spoilage where vegetable, fruits, meats, fish and other products must be washed in water before packaging.
3. UV purification is particularly useful in applications where chlorine-free, de-ionized and/or carbon filtered water are extensively employed. Unattended carbon filters and ion-exchange tanks act as incubators for bacteria accumulation.
   - for electronics; in conjunction with de-ionized and high purity water systems.
   - for pharmaceuticals and cosmetics; strict water treatment standards are necessary for strict maintenance of product's quality control.
   - for biological laboratories; sterile water is required for testing and research work.
   - for hospitals; provides ultra-pure water on demand for maternity labor and delivery areas, pathology labs, etc.
4. In industrial pollution control, it affords an excellent end-treatment for positive protection in wastewater control systems.
   - for selective use as a tertiary treatment for bacteria destruction after removal of chemicals and other objectionable ingredients.

Chlorine Versus Ultraviolet Purification

As a tertiary treatment for water, chlorination offers the advantage of continued disinfection after initial treatment, since some chlorine remains in the water with residual germ-fighting action. The ultraviolet method, however, has none of the following disadvantages of chlorine:

1. Chlorine treatment requires operation attention.
2. In small installations, when chlorine gas is liberated from a chlorine cylinder or moistened crystals or pellets, the fumes are extremely dangerous and may even be lethal.
3. Chlorine itself is a highly corrosive and toxic chemical.
4. Chlorine is an additive material which may impart an undesirable taste to the water and a decrease in pH.
5. Chlorine is chemically active and can react with foreign ingredients (e.g., in industrial waste-waters) to form toxic compounds, a matter of increasing concern to the Federal Government and to many states and municipalities.
   - it may combine with ammonia to form "chloramine" which is acutely toxic to fish even at low concentration.
   - it may combine with phenol to form "clorophenols," another dangerously toxic compound.

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