2.2 Desalination Technologies and Filtration Processes

Out of the several desalination processes considered, reverse osmosis, ion exchange, distillation and electrodialysis are the major processes used in desalination. Of lesser significance due to their practical application as well as their less beneficial operation, are refrigerant freezing, vacuum freezing, vapor compression and piezodialysis.

Reverse osmosis is in general the most economical process for desalination of brackish water and sea water. As a widely accepted technology, reverse osmosis became more and more competitive and is superior to the traditional thermal process when a comparison is made of capital investment and energy consumption.

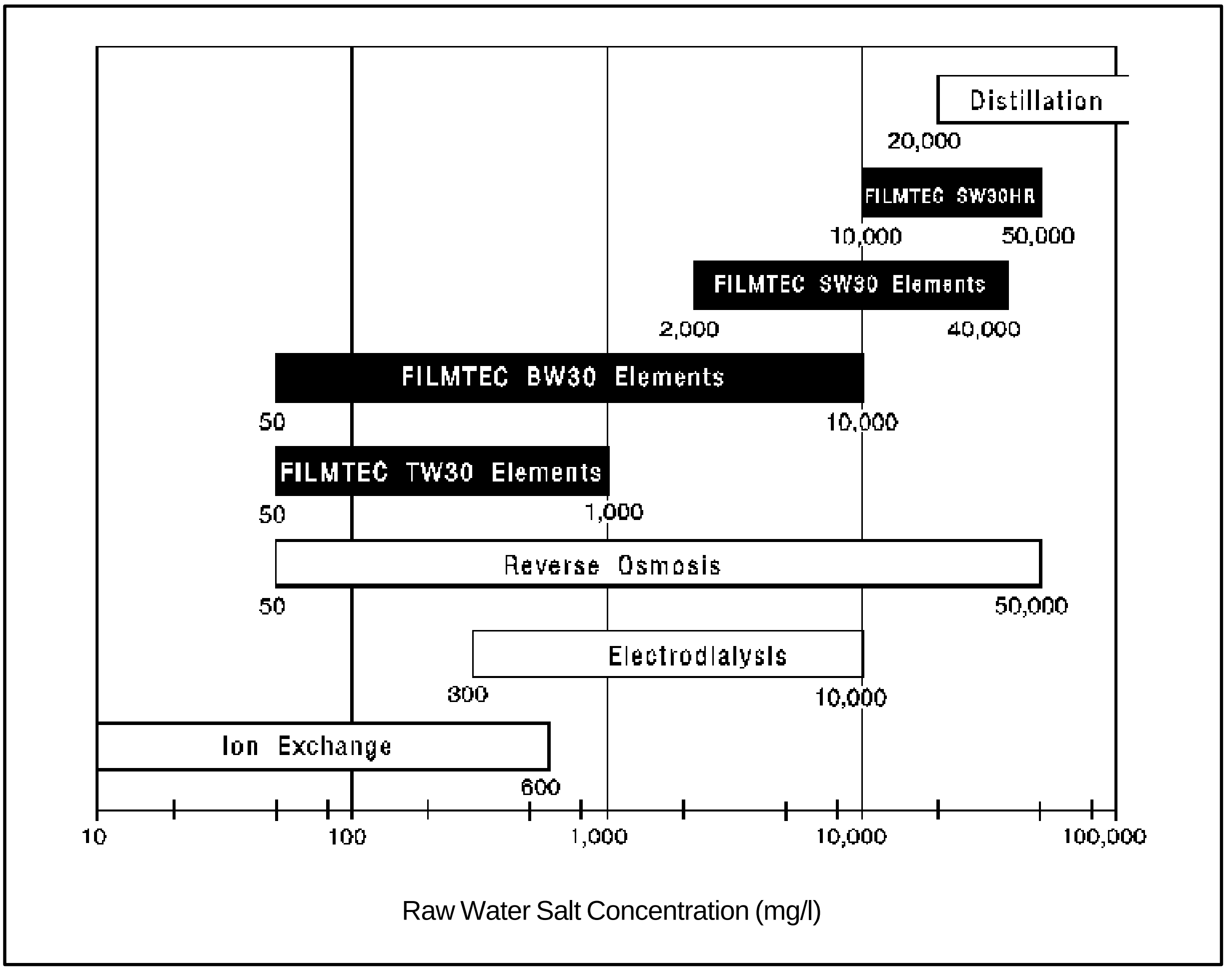


Figure 1: Major Desalination Processes

The most typical operating span of these four major desalination processes is shown in Figure 1, indicating also the standard operating ranges of the different FILMTEC® element types.
The various filtration technologies which currently exist can be categorized on the basis of the size of particles removed from a feed stream. Conventional macrofiltration of suspended solids is accomplished by passing a feed solution through the filter media in a perpendicular direction. The entire solution passes through the media, creating only one exit stream. Examples of such filtration devices include cartridge filters, bag filters, sand filters, and multimedia filters. Macrofiltration separation capabilities are generally limited to undissolved particles greater than 1 micron.

For the removal of small particles and dissolved salts, membrane separation systems are utilized which use a different method than conventional particle filtration. Termed crossflow membrane filtration (see Figure 2), this method uses a pressurized feed stream which flows parallel to the membrane surface. A portion of this stream passes through the membrane, leaving behind the rejected particles in the concentrated remainder of the stream. Since there is a continuous flow across the membrane surface, the rejected particles do not accumulate but instead are swept away by the concentrate stream. Thus, one feed stream is separated into two exit streams: the solution passing through the membrane surface (permeate) and the remaining concentrate stream.

There are four general categories of crossflow membrane filtration: Microfiltration, Ultrafiltration, Nanofiltration, and Reverse Osmosis.

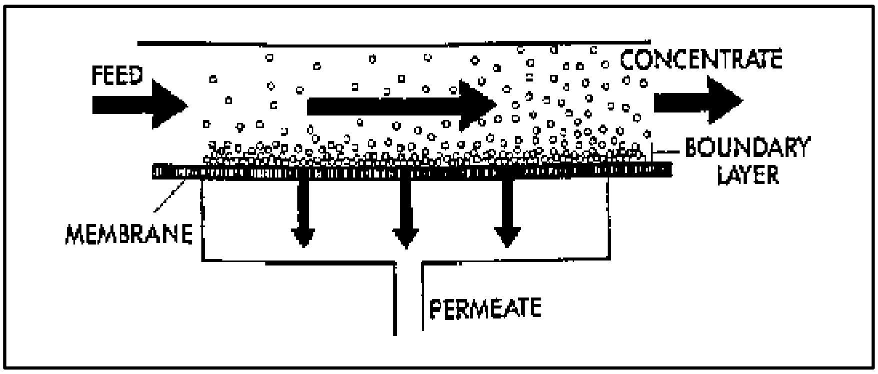


Figure 2: Crossflow Membrane Filtration

Microfiltration (MF)
Microfiltration removes particles in the range of approximately 0.1 to 1 micron. In general, suspended particles and large colloids are rejected while macromolecules and dissolved solids pass through the MF membrane. Applications include removal of bacteria, flocculated materials, or TSS (total suspended solids). Transmembrane pressures are typically 0.7 bar (10 PSI).

Ultrafiltration (UF)
Ultrafiltration provides macromolecular separation for particles in the 20 to 1,000 Angstrom range (up to 0.1 micron). All dissolved salts and smaller molecules pass through the membrane. Items rejected by the membrane include colloids, proteins, microbiological contaminants, and large organic molecules. Most UF membranes have molecular weight cut-off values between 1,000 and 100,000. Transmembrane pressures are typically 1 to 7 bar (15 to 100 PSI).

Nanofiltration (NF)
Nanofiltration refers to a speciality membrane process which rejects particles in the approximate size range of 1 nanometer (10 Angstroms), hence the term "Nanofiltration." NF operates in the realm between UF and reverse osmosis. Organic molecules with molecular weights greater than 200-400 are rejected. Also, dissolved salts are rejected in the range of 20-98%. Salts which have monovalent anions (e.g. sodium chloride or calcium chloride) have rejections of 20-80%, whereas salts with divalent anions (e.g. magnesium sulfate) have higher rejections of 90-98%. Typical applications include removal of color and total organic carbon (TOC) from surface water, removal of hardness or radium from well water, overall reduction of total dissolved solids (TDS), and the separation of organic from inorganic matter in specialty food and wastewater applications. Transmembrane pressures are typically 3.5 to 16 bar (50 to 225 PSI).

Reverse Osmosis (RO)
Reverse osmosis is the finest level of filtration available. The RO membrane acts as a barrier to all dissolved salts and inorganic molecules, as well as organic molecules with a molecular weight greater than approximately 100. Water molecules, on the other hand, pass freely through the membrane creating a purified product stream. Rejection of dissolved salts is typically 95 to greater than 99%.

The applications for RO are numerous and varied, and include desalination of sea water or brackish water for drinking purposes, wastewater recovery, food and beverage processing, biomedical separations, purification of home drinking water and industrial process water.

Also, RO is often used in the production of ultrapure water for use in the semiconductor industry, power industry (boiler feed water), and medical/laboratory applications. Utilizing RO prior to Ion Exchange (IX) dramatically reduces operating costs and regeneration frequency of the IX system. Transmembrane pressures for RO typically range from 14 bar (200 PSI) for brackish water to 69 bar (1,000 PSI) for sea water.

The normal range of filtration processes is shown in Figure 3:

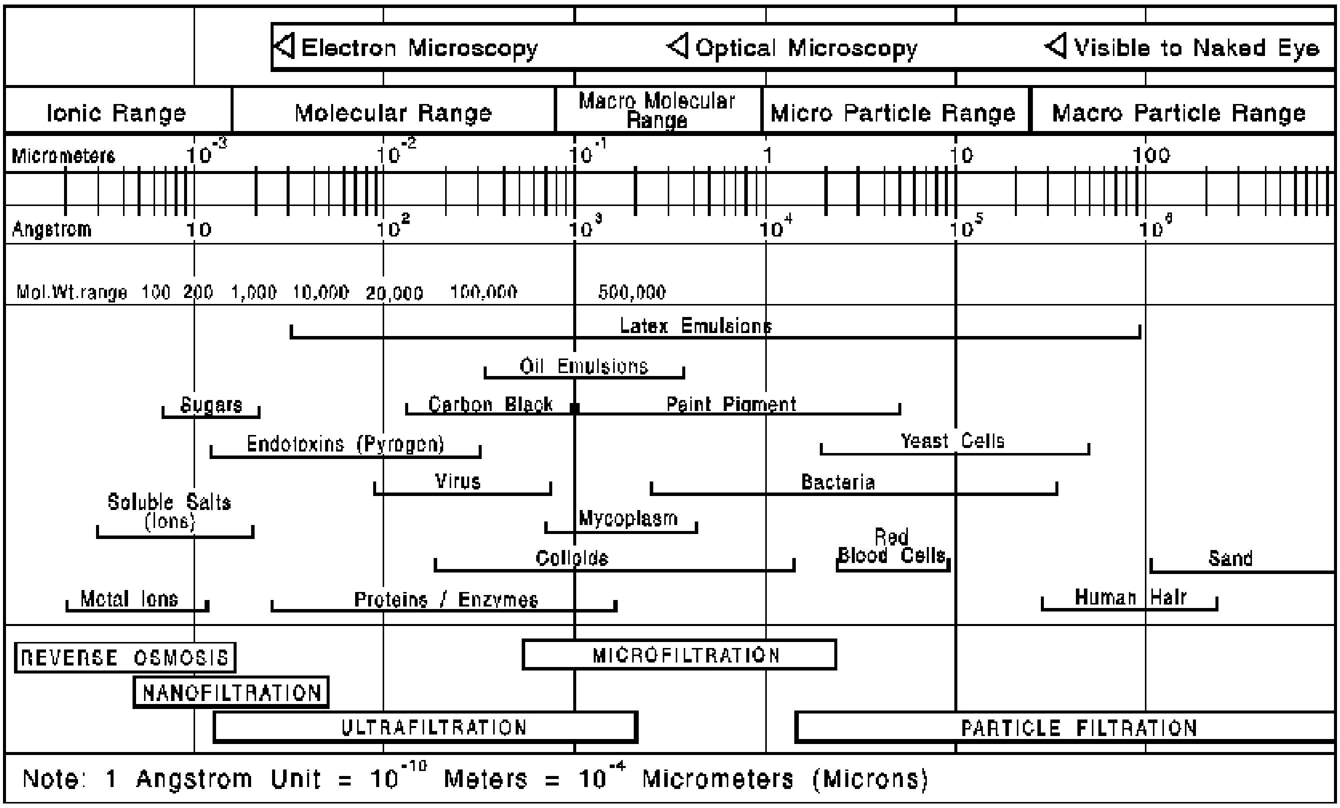


Figure 3: Ranges of Filtration Processes

2.3 Principle of Reverse Osmosis

2.3.1 How Reverse Osmosis Works

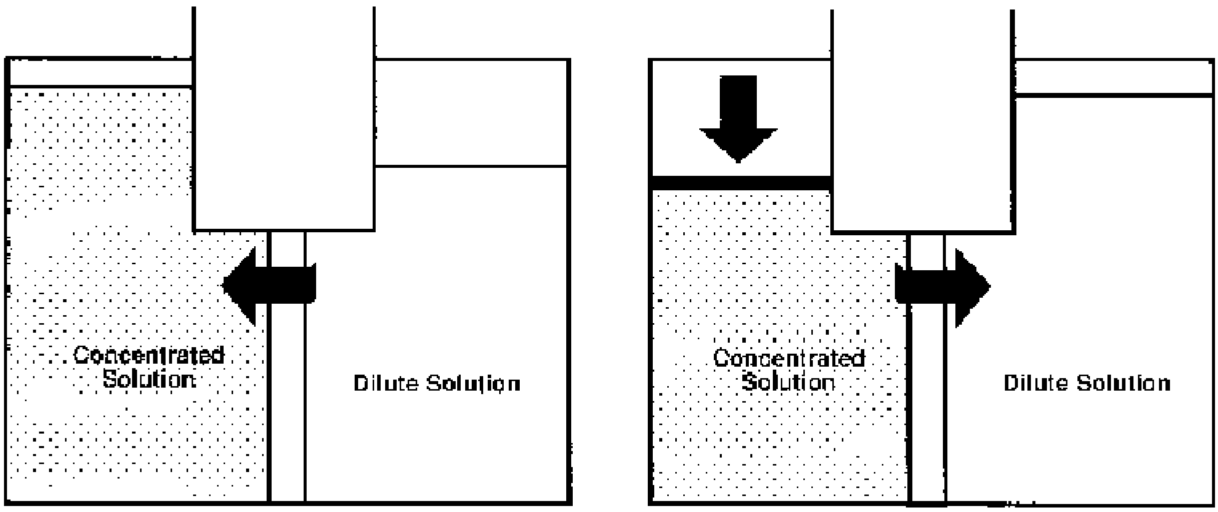
The phenomenon of osmosis occurs when pure water flows from a dilute saline solution through a membrane into a higher concentrated saline solution.

The phenomenon of osmosis is illustrated in Figure 1. A semi-permeable membrane is placed between two compartments. "Semi-permeable" means that the membrane is permeable to some species, and not permeable to others. Assume that this membrane is permeable to water, but not to salt. Then, place a salt solution in one compartment and pure water in the other compartment. The membrane will allow water to permeate through it to either side. But salt cannot pass through the membrane.

As a fundamental rule of nature, this system will try to reach equilibrium. That is, it will try to reach the same concentration on both sides of the membrane. The only possible way to reach equilibrium is for water to pass from the pure water compar-tment to the salt-containing compartment, to dilute the salt solution.

Figure 1 also shows that osmosis can cause a rise in the height of the salt solution. This height will increase until the pressure of the column of water (salt solution) is so high that the force of this water column stops the water flow. The equilibrium point of this water column height in terms of water pressure against the membrane is called osmotic pressure.

If a force is applied to this column of water, the direction of water flow through the membrane can be reversed. This is the basis of the term reverse osmosis. Note that this reversed flow produces a pure water from the salt solution, since the membrane is not permeable to salt.



Osmosis

Water diffuses through a semi-permeable membrane toward region of higher concentration to equalize solution strength. Ultimate height difference between columns is "osmotic" pressure.

Reverse Osmosis

Applied pressure in excess of osmotic pressure reverses water flow direction. Hence the term "reverse osmosis."

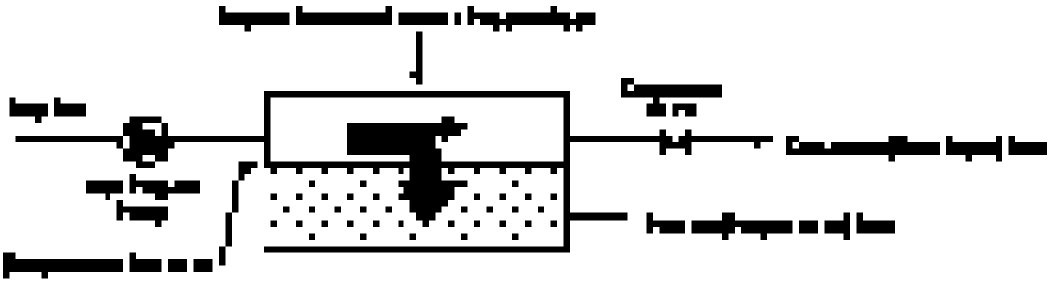
Figure 1: Overview of Osmosis / Reverse Osmosis

2.3.2 How to Use Reverse Osmosis in Practice

The simplified reverse osmosis process is shown in Figure 2.

With a high pressure pump, pressurized saline feed water is continuously pumped to the module system. Within the module, consisting of a pressure vessel (housing) and a membrane element, the feed water will be split into a low-saline product, called permeate and a high saline brine, called concentrate or reject. A flow regulating valve, called concentrate valve, controls the percentage of feedwater that is going to the concentrate stream and the permeate which will be obtained from the feed.

In the case of a spiral wound module consisting of a pressure vessel and several spiral wound elements, pressurized water flows into the vessel and through the channels between the spiral windings of the element. Up to seven elements are connected together within a pressure vessel. The feedwater becomes more and more concentrated and will enter the next element, and at last exits from the last element to the concentrate valve where the applied pressure will be released. The permeate of each element will be collected in the common permeate tube installed in the center of each spiral wound element and flows to a permeate collecting pipe outside of the pressure vessel.



$$\text{Recovery (\%)} = \frac{\text{Permeate Flow} \cdot 100}{\text{Feed Flow}}$$

$$\text{Salt Passage (\%)} = \frac{\text{Permeate Salt Concentration} \cdot 100}{\text{Feed Salt Concentration}}$$

$$\text{Salt Rejection (\%)} = 100 - \text{Salt Passage}$$

Figure 2: Reverse Osmosis Process

2.3.3 Reverse Osmosis Module Designs

Four basic types of RO module designs are in commercial use: tubular, plate-and-frame, spiral wound, and hollow fiber modules.

The tubular and the plate-and-frame devices date back to the early days of RO membrane technology. Both of these designs involve a high initial capital cost and a low membrane packing density (very low for the tubular design). However, these designs can operate on highly fouling feedwaters. Thus, these designs find use in the food industry (examples: milk concentration for cheese manufacture, tomato juice concentration), and in concentration/ treatment of wastewaters. They seldom compete with spirals and hollow fiber modules in desalination and water purification applications.

The design of spiral wound elements contains two layers of membrane glued back-to-back onto a permeate collector fabric (permeate channel spacer). This membrane envelope is wrapped around a perforated tube into which the permeate empties from the permeate channel spacer. A plastic netting is wound into the device, and maintains the feedstream channel spacing. It also promotes mixing of the feedstream to minimize concentration polarization.

The design of a hollow fiber permeator can package a tremendous amount of membrane area into a small volume. The difficulty in this approach, however, is that these fibers act almost like a string filter. This design requires a high level of feedwater pretreatment to minimize the fouling potential of the feedwater. And when they are fouled, they are very difficult to regenerate by cleaning methods. Another aspect of hollow fiber permeators is that abrasion through fiber-fiber contact or via fiber contact with trapped particles appears to occur during RO operation. This results in gradual fall-off of salt rejection with time.

Below is a set of comparisons between the four basic module designs. Comparing their susceptibility to fouling for example, hollow fiber devices are much worse than spiral wound devices, which in turn are much worse than tubular devices and plate-and-frame devices.

As for system space requirements, tubular modules require the most space, hollow fiber and spiral modules require the least space.

One specific advantage of spiral wound units is that they can be linked together into series of two to seven elements within a single pressure vessel. Thus, up to seven times the flow of product water can be handled with only a single set of plumbing connections for feed, concentrate and permeate to a pressure vessel. In the case of hollow fiber modules, each hollow fiber unit requires installation of one feedwater inlet, one concentrate outlet, and one permeate outlet. For large modular systems for field application, a significant percentage of the system cost will be in the plumbing connections.

Comparisons of Reverse Osmosis System Types

System Costs:
Tubular, plate & frame >> hollow fiber, spiral

Flexibility in Design:
Spiral >> hollow fiber > plate & frame > tubular

Cleaning Behaviour:
Plate & frame > tubular > spiral > hollow fiber

System Space Requirements:
Tubular >> plate & frame > spiral > hollow fiber

Susceptibility to Fouling:
Hollow fiber >> spiral > plate & frame > tubular

Energy Requirement:
Tubular > plate & frame > hollow fiber > spiral

Referring to system costs, spiral wound and hollow fiber systems are relatively equal on well water sources. For surface water sources, pretreatment costs tend to be higher for hollow fiber systems because of their fouling potential. Tubular and plate-and-frame systems are far more expensive than hollow fiber and spiral wound devices, and are relatively cost competitive to each other.

2.4 FT30 Membrane Description

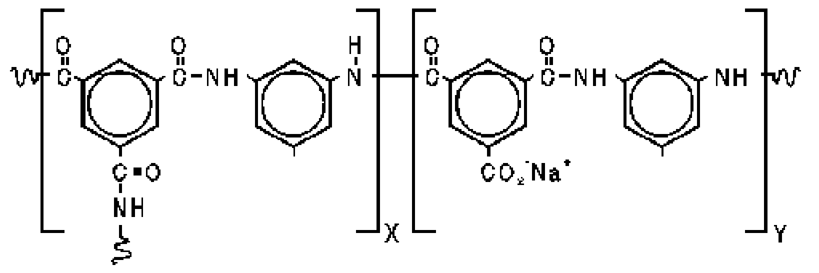
Composition of the FT30 membrane
The FILMTEC® FT30 thin film composite reverse osmosis membrane is made from one of the simplest aromatic diamines: 1,3-benzene-diamine (meta phenylene diamine). The final chemical structure of the membrane is believed to be as shown in Figure 1.

Thin Film Composite Configuration
The FT30 membrane is defined as a thin film composite membrane consisting of three layers: a polyester support web, a microporous polysulfone interlayer, and an ultra thin barrier layer on the top surface. A schematic diagram of the membrane is shown in Figure 2.

The major structural support is provided by the non-woven web, which has been calendered to produce a hard, smooth surface free of loose fibers. Since the polyester web is too irregular and porous to provide a proper substrate for the salt barrier layer, a microporous layer of engineering plastic (polysulfone) is cast onto the surface of the web.

The polysulfone coating is remarkable in that it has surface pores controlled to a diameter of approximately 150 Angstroms. The FT30 barrier layer, about 2,000 Angstroms thick, can withstand high pressures because of the support provided by the polysulfone layer. Because of its barrier layer thickness, FT30 is very resistant to mechanical stresses and chemical degradation.

Figure 3 shows an SEM-photograph of a cross-section of the FILMTEC FT30 membrane.



FT30 polyamide is cross-linked and contains carboxylate groups

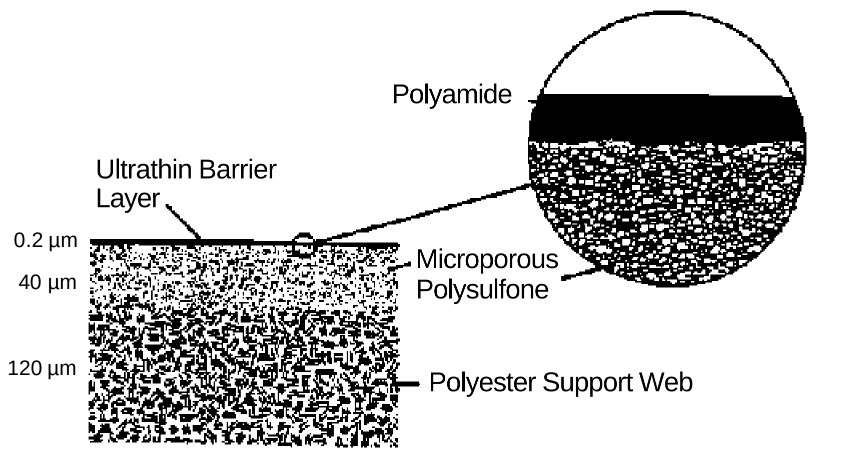


Figure 2: Schematic Cross-Section of Thin Film Composite Reverse Osmosis Membrane

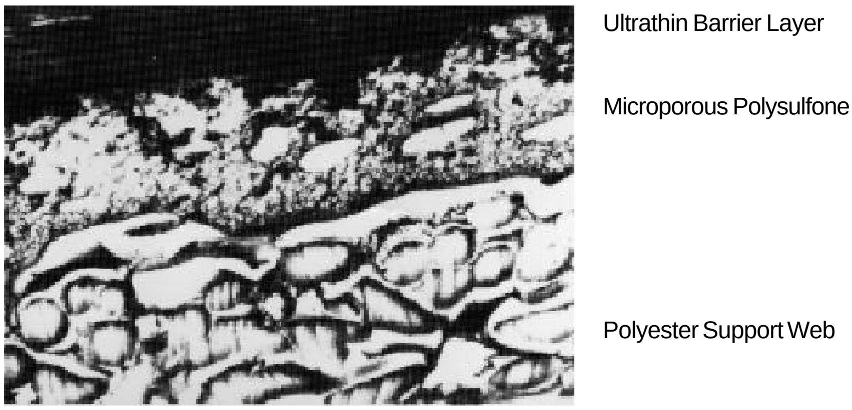


Figure 3: SEM Photograph of a Cross-Section of the FILMTEC FT30 Membrane

Figure 1: FILMTEC FT30 Membrane Structure

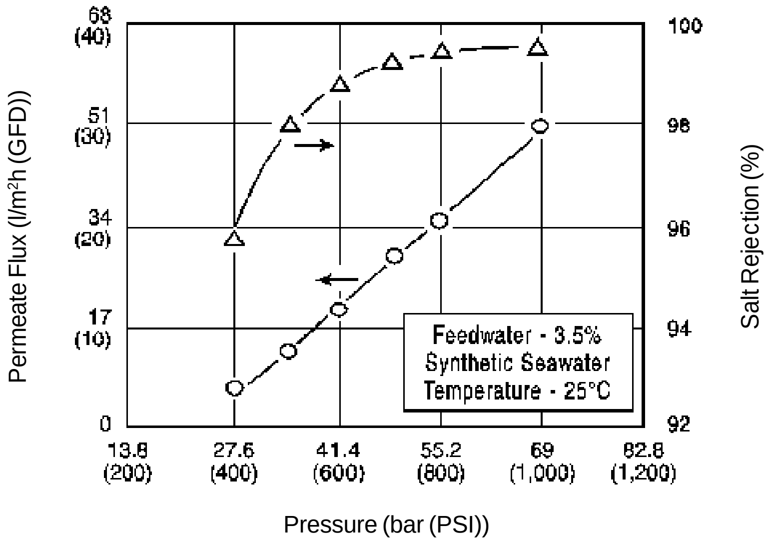
2.5 Membrane Specifications

FILMTEC® thin film composite reverse osmosis (RO) membranes give excellent performance for a wide variety of applications, including low-pressure tapwater use, single-pass sea water and brackish water desalination, chemical processing and waste treatment. This membrane exhibits excellent performance in terms of flux, salt rejection, and microbiological resistance. FILMTEC elements can operate over a pH range of 2 to 11, are resistant to compaction and are suitable for temperatures up to 45°C.

FILMTEC spiral wound elements have been extensively used since 1980. In numerous trials under actual sea water conditions, FT30 elements have provided salt rejections of better than 99.5% and fluxes of 24 l/m^{2}h (14 GFD). On a 0.2% salt solution at 15.5 bar (225 PSI), rejections above 98% and fluxes of 40 l/m^{2}h (24 GFD) are routinely obtained.

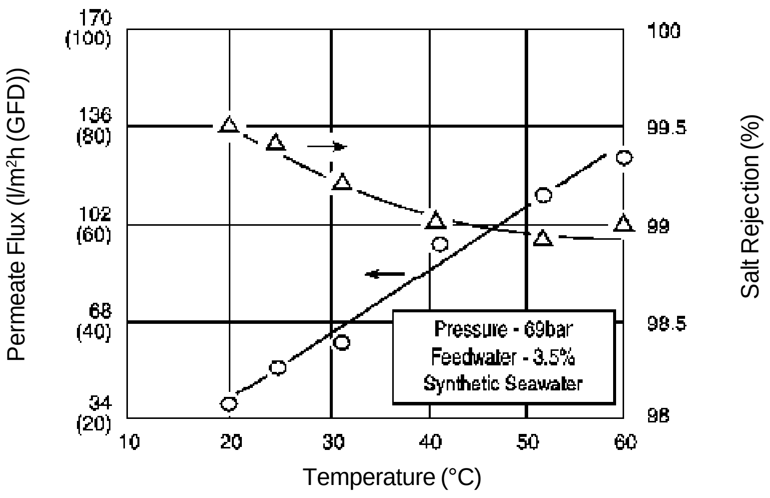
Figures 1 to 4 show the performance of the FT30 membrane (SW grade) vs. pressure, temperature, feedwater pH and feedwater salt concentration.

Typical solute rejections of FT30 membrane are shown in Table 1.



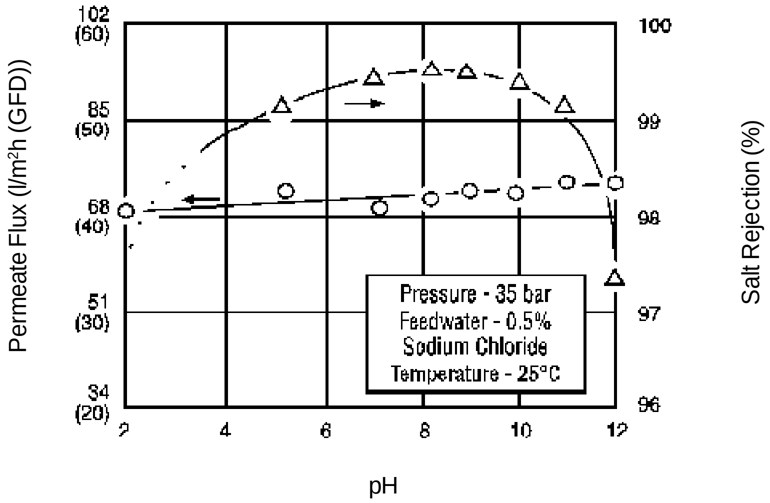
Results: Permeate flux increases linearly with pressure. Salt rejection reaches a plateau at about 60 l/m^{2}h flux. Intercept at zero permeate flux is approximate osmotic pressure of feedwater.

Figure 1: Feedwater Pressure - Effect on FT30 Flux & Salt Rejection



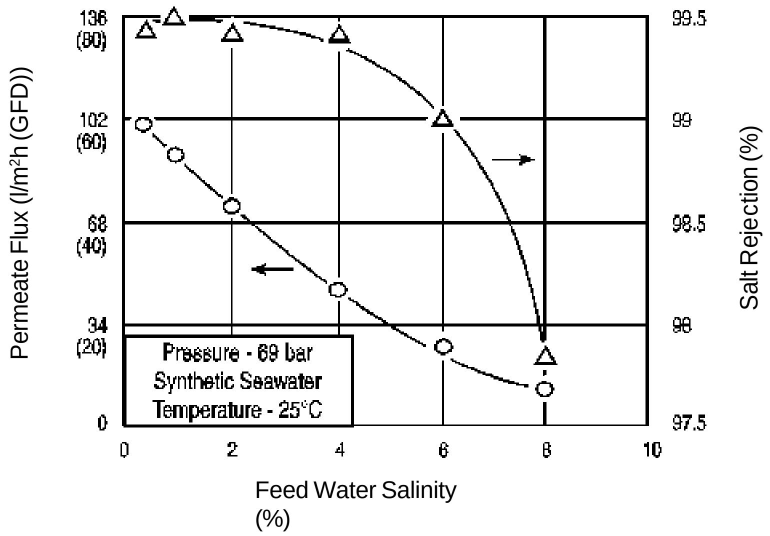
Results: Flux increases almost linearly with temperature. Salt rejection falls off with increasing temperature. Some hysteresis is evident in flux curves for temperature cycles (not shown) but not in salt rejection curves.

Figure 2: Feedwater Temperature - Effect on FT30 Flux & Salt Rejection



Results: Salt rejection and flux are rather constant over a broad pH range. Maximum salt rejection occurs at pH 8.5.

Figure 3: Feedwater pH - Effect on FT30 Flux & Salt Rejection



Results: Permeate flux will decrease as feedwater salinity increases. Salt rejection eventually also declines when permeate flux becomes insufficient.

Figure 4: Feedwater Concentration - Effect on FT30 Flux & Salt Rejection

Table 1: Typical Solute Rejections of FT30 Membrane

Solute	MW	Rejection (%)		
		BW Grade	SW Grade	SW HR Grade
Sodium Fluoride NaF	42	99	>99	>99
Sodium Cyanide NaCN (pH 11)	49	97	98	99
Sodium Chloride NaCl	58	99	>99	>99
Silica SiO_2 (50 ppm)	60	98	99	>99
Sodium Bicarbonate $NaHCO_3$	84	99	98	99
Sodium Nitrate $NaNO_3$	85	97	96	98
Magnesium Chloride $MgCl_2$	95	99	>99	>99
Calcium Chloride $CaCl_2$	111	99	>99	>99
Magnesium Sulfate $MgSO_4$	120	>99	>99	>99
Nickel Sulfate $NiSO_4$	155	>99	>99	>99
Copper Sulfate $CuSO_4$	160	>99	>99	>99
Formaldehyde	30	35	50	60
Methanol	32	25	35	40
Ethanol	46	70	80	85
Isopropanol	60	90	95	97
Urea	60	70	80	85
Lactic Acid (pH 2)	90	94	97	98
Lactic Acid (pH 5)	90	99	>99	>99
Glucose	180	98	99	>99
Sucrose	342	99	>99	>99
Chlorinated Pesticides (traces)	-	>99	>99	>99

Standard Conditions

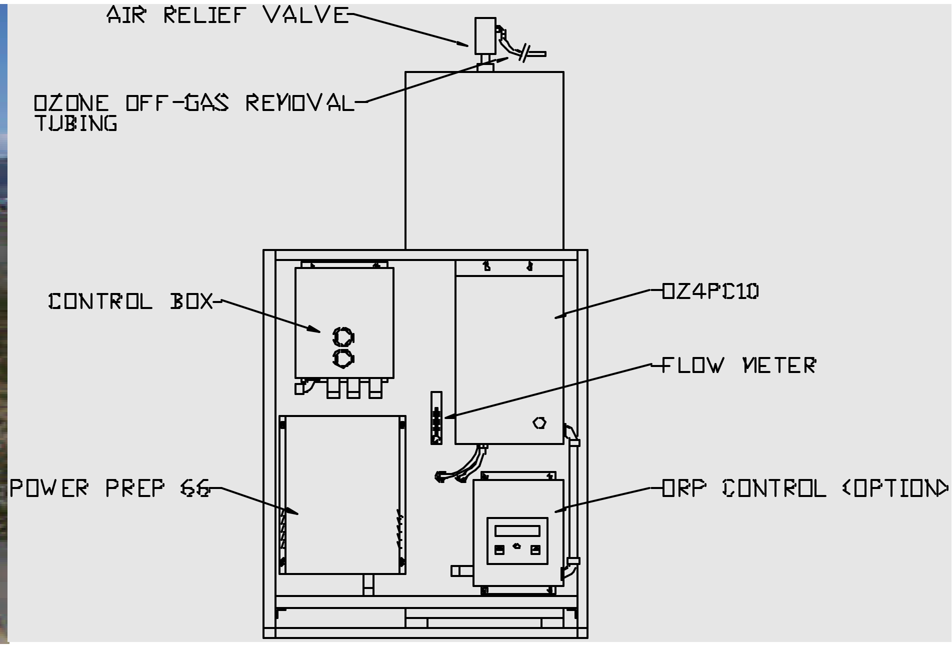
2,000 ppm Solute, 225 PSI Feed Pressure (1,6 MPa)
Feed Temperature 77°F (25°C), Feed pH 7 (unless otherwise noted)

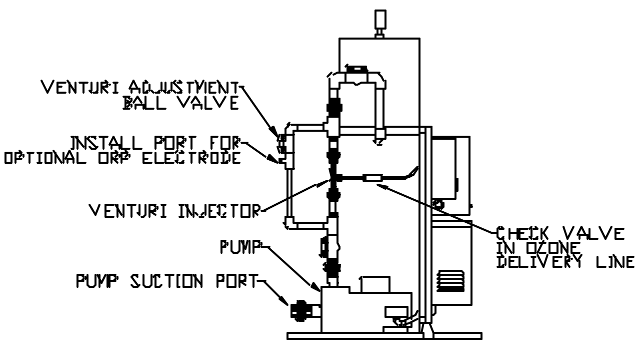
As a general rule, the rejection of a solute increases from the BW grade to the SWHR grade membrane, and with the

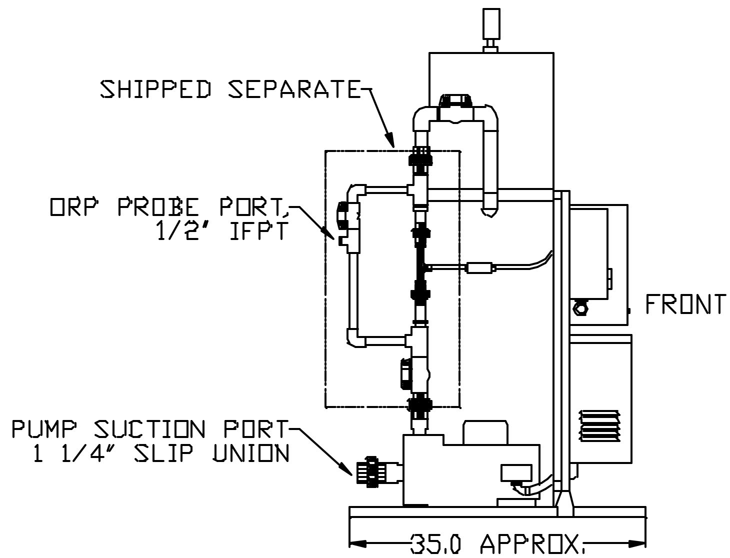
- degree of dissociation
- ionic change
- molecular weight
- nonpolarity
- degree of molecular bran-ching

of the considered chemical compound.

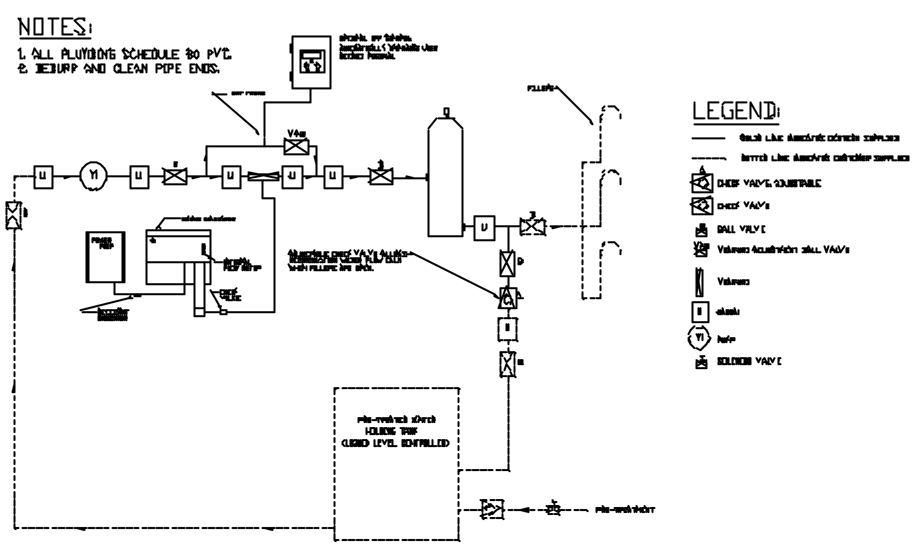
<u>5-10 GPM</u> Ozone System







TYPICAL BOTTLED WATER SETUP WITH RECIRCULATION & TREATED HOLDING TANK



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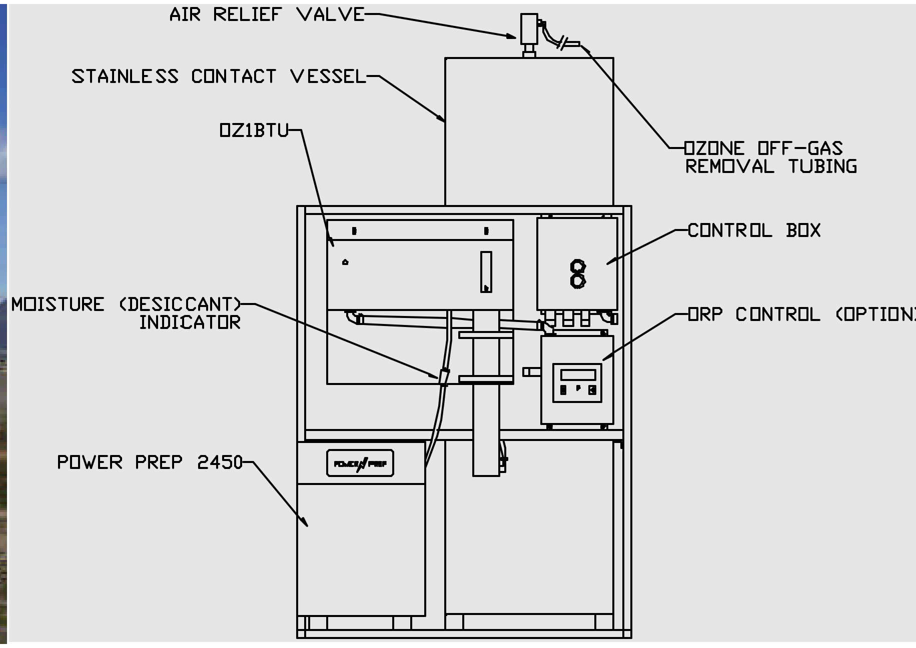
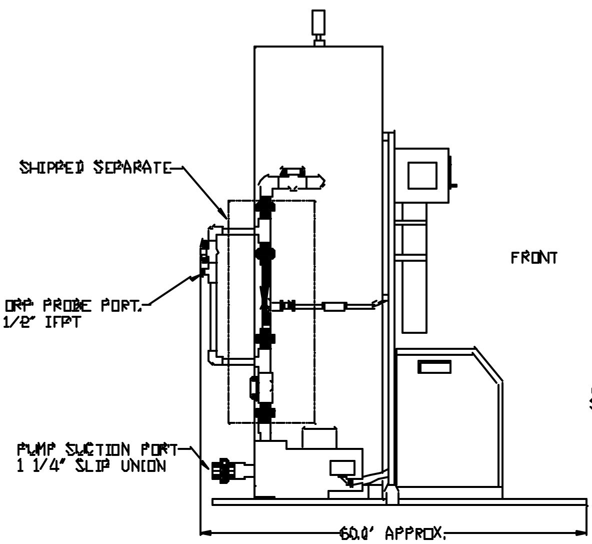
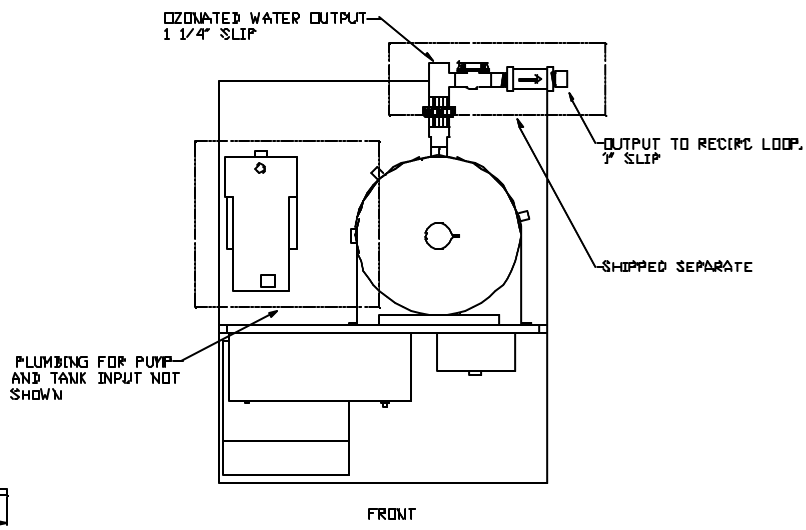
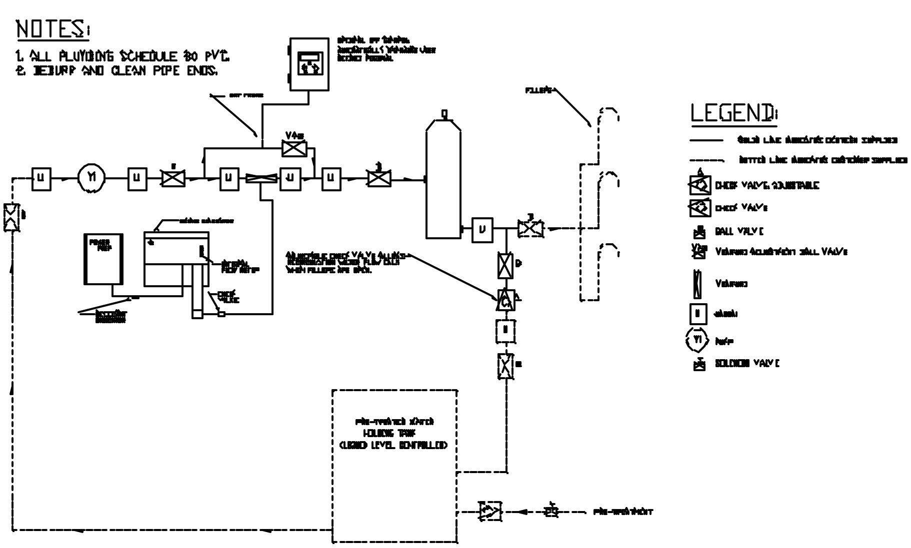
11-20 GPMOzone System



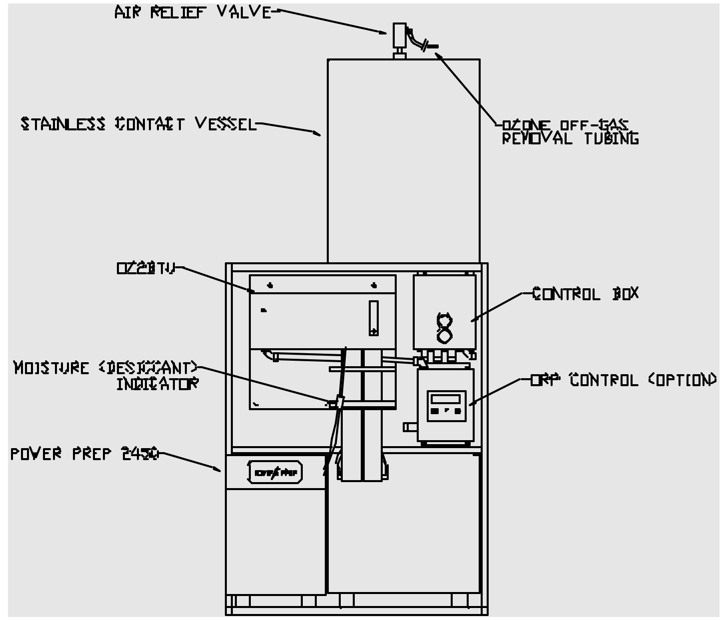


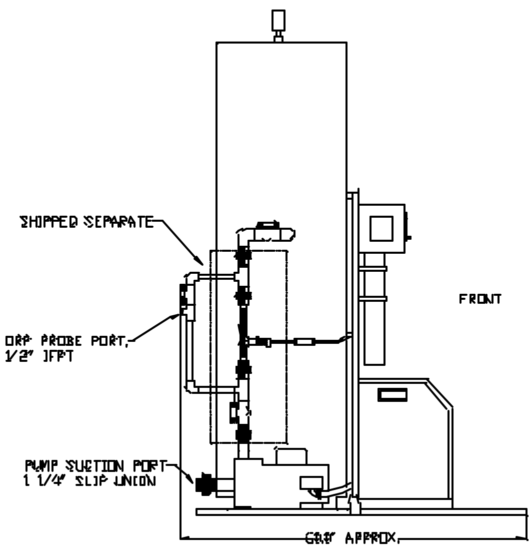


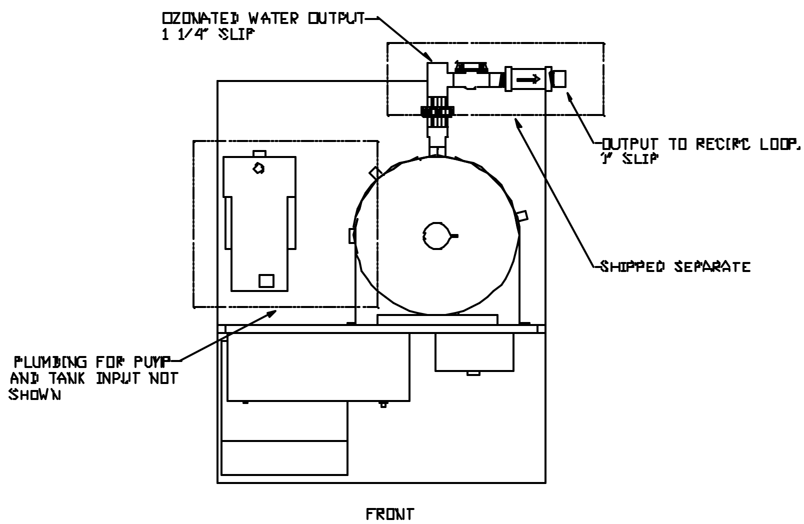
Typical Bottled Water Setup with Recirculation & Treated Holding Tank



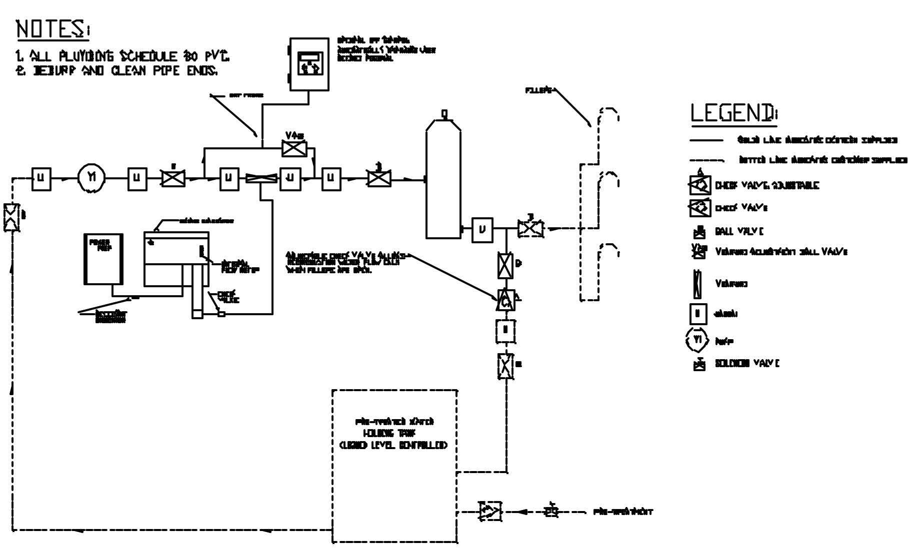
21-30 GPM Ozone System







Typical Bottled Water Setup with Recirculation & Treated Holding Tank



System Generator and Air Preparation Maintenance Kits

A - Denotes positive pressure systems kits
B - Denotes negative pressure systems kits

Generator	Maintenance Kit	Part #
OZ4PC10	MK1248PC-A	33118
OZ1BTU	MK12BT-A	33115
OZ2BTU	MK12BT-A	33115

System Standard Accessories

System Model	Warranty Card	Spare Fuse	O & M Manual	Installation Manual	C/D Removal
5-10 GPM	T	T	T	T	T
11-20 GPM	T	T	T	T	—
21-30 GPM	T	T	T	T	—

Available System Options

System Model	220V 60 Hz or 50 Hz	ORP Control
5-10 GPM Bottled Water System	T	T
11-20 GPM Bottled Water System	T	T
21-30 GPM Bottled Water System	T	T

Bottled Water System Series

60 GPM
Part # 30278

Features (All):

- Engineered for "turn key" operation
- Simple installation
- 4 wire 220V 60 Hz input
- Pre-plumbed and wired
- Designed for use with pretreated water
- Aluminum extruded frame mounting
- Engineered to meet FDA and IBWA ozone residual specifications
- FDA approved materials

Ozone Equipment: (60 GPM)

- OZ6BTU ozone generator
- 2- Power Prep Titans
- 2– 122 gal. SS contact tanks
- On-off control box
- Schedule 80 plumbing
- Natural Kynar venturi injector
- 5 hp stainless steel pump
- 2- AR-1 air relief valves

Shipping & Lead Time:

Weight:	1250 lbs
Dimensions:	64"W x 61"D x 93"H
Maximum lead-time:	30 days

Bottled water systems are engineered to ensure ozone residuals meet the FDA and IBWA mandated standards. These systems are designed to be used with pre-treated water. The use of high purity components such as natural Kynar venturi injectors, stainless steel tanks and rust proof extruded aluminum frames are among some of the features included with these systems.

ZYI Corp. can expand system capabilities to meet with different flow rates.

Replacement parts are listed in the operation and maintenance manuals supplied with equipment. ZYI generators should be accompanied by air preparation.

30278	30-60 GPM frame mounted bottled water system (220 Vac, 60 Hz)
	Optional ORP monitor (contact factory)

ZYI Corporation

WHAT IS OZONE?

Ozone is a molecule consisting of three oxygen atoms linked together sharing the electrons surrounding the nucleus of each atom. Normally two atoms of oxygen link up together forming the relatively stable O2 molecule that is the vital part (about 20%) of the air we breath.

Ozone is generated by nature but it can also be generated artificially by passing air (or oxygen) through an electric discharge. This configuration of oxygen, namely three atoms linked together, form a very unstable gas and a very reactive molecule. The extra atom detaches itself from the other two very readily and reacts almost immediately with surrounding materials. This triple oxygen molecule is a very powerful oxidizing agent, much more powerful than the double oxygen molecule itself. It is this free atom discharging from the other two atoms that makes ozone one of the most powerful disinfectants known to man.

As a disinfectant, in gaseous form or dissolved in an aqueous solution, it quickly destroys the microorganisms it comes in contact with leaving behind only common oxygen, the kind we breathe all the time. It does not leave any residual of any kind that would be harmful or undesirable in any way. It kills microorganisms and changes undesired chemical compounds (such as ethylene) into more innocuous substances. As a disinfectant, it is much more powerful than chlorine and does not have an unpleasant taste.

THE STORY OF OZONE

Ozone is generated naturally when lightning bolts send electric charges through the air; ozone is one of the most powerful disinfectants and oxidants known to man. This is why the air smells so fresh after a thunderstorm.

Ozone is generated artificially by passing air or oxygen through an electric discharge. Ozone is a form of oxygen that has three atoms per molecule (O_3) rather than the usual two; ozone is an unstable gas that naturally decomposes into ordinary oxygen. Ozone As a disinfectant, ozone quickly destroys the bacteria it contacts, leaving only common oxygen behind. As oxidants, the atoms adhere to existing chemical compounds, and change them to more-innocuous substances.

Europeans have relied on the technology to treat drinking water for nearly a century. The United States has been slow to adopt ozonation, largely because chlorination has been less costly. Now, however, concerns about human health and the environment are converting both people and industry to this technology. In 1991, the U.S. Environmental Protection Agency confirmed that ozone is the most effective primary disinfectant available for drinking water. Moreover, with an oxidation capacity 352% greater than chlorine's and 3000 times faster acting, ozone can eliminate odor and color problems and can degrade harmful organic compounds.

Disinfecting by Ozone occurs through the rupture of the cell wall. This is a more efficient method than Chlorine, which depends upon diffusion into the cell protoplasm and inactivation of the enzymes. An ozone level of 0.4 PPM for 4 minutes will kill all bacteria, virus, and fungus.

Ozone is less dependent on the pH of the water, compared to other sanitizing chemicals.

Gaseous ozone is extremely effective against aerobic microorganisms such as fungi ozone is a faster acting germicide, compared to other sanitizing agents. There is a broad range of germicidal activity; no microorganisms are spared. Ozone is the most effective single disinfectant against Cryptosporidium. Microorganisms do not become "resistant" to ozone. Ozone is not carcinogenic Ozone is a faster acting oxidizing agent. Ozone is 350 times stronger than Chlorine and 3000 times' faster acting. Ozone has no chemical residual after treatment of agricultural commodities There is no storage of toxic chemicals required Ozone is produced as needed, or on-demand.

ZYI Corporation

Enhancing Food Safety with Ozone

The adoption of ozone technology in food processing depends upon economic competitiveness with existing and emerging technologies that sanitizes food, as well as its effectiveness in enhancing food safety. Ozone, gained approval for use in the U.S. food processing industry to help rid food of dangerous pathogens (bacteria, parasites, fungi, and viruses). In July 1997, ozone was deemed "generally recognized as safe" (GRAS) as a disinfectant for foods by an independent panel of experts sponsored by the Electric Power Research Institute.

For any substance commonly used in the U.S. prior to January 1, 1958, the Food and Drug Administration (FDA) allows its use in other products if an Independent panel of experts deems the substance and its use as GRAS. The GRAS determination in treating food products was an expansion of uses already approved for ozone.

Prior to July 1997, however, the only approved use of ozone in food products was for the storage of meat in gaseous ozone, granted by USDA in 1957. Now, processors of fresh fruit, vegetables, poultry, and red meat are examining ozone as one of several new technologies to ensure food safety.

Potential Benefits

The U.S. Environmental Protection Agency, in conjunction with the Safe Drinking Water Act of 1991,confirmed that ozone was effective in ridding water of hazardous pathogens, including chlorine-resistant Cryptosporidium.

Coupling two processes---washing food with ozonated water and the subsequent ozonation of the recaptured water--reduces the amount of water needed in the Food washing system (which lowers costs, particularly for high-water users such as fruit and vegetable packers and processors). In addition, any wastewater discharged by an ozonation process, is free of chemical residuals, a growing environmental concern in groundwater pollution.

Food products treated with ozone are also free of disinfectant residues. Ozone also acts as a disinfectant in its gaseous state. It can be applied to sanitize food storage rooms and packaging materials, which may help to control insects during storage of foods and prevent spoilage of produce during shipping. Gaseous ozone is also listed as an alternative disinfectant for water-sensitive produce, such as strawberries and raspberries in the Guide to Minimizing Microbial Food Safety Hazards for Fresh Fruits and Vegetables (a document forthcoming from FDA and USDA).

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Interest in Ozone Systems Builds

The food processing industry has faced mounting concerns in recent years about its ability to provide a consistently safe food supply. Food passes through many hands--from growing, picking, and boxing, shipping, to final processing-- prior to reaching the consumer. Most past efforts to avoid contamination of food centered on preventing exposure to sewage or animal manure early in the production process.

Because of the incidence of food contamination along the entire chain of production, and the recognition that many pathogens--some have recently emerged--are found in even healthy animals, the industry has realized that some form of disinfecting, perhaps at multiple points, is necessary. Each year in the U.S., an estimated 6.5-33 million illnesses and up to 9,000 deaths are caused by foodborne diseases.

As a method of disinfecting food, ozonation reportedly does not alter taste, unlike some heat-based steam and flash pasteurization systems that cook the product. Further, in some foods, ozone proponents indicate flavor is enhanced by ozone's ability to neutralize chemicals, pesticides, and bad tastes from gases produced by ripening or decay.

Recent televised news reports highlighted a Florida citrus grower washing oranges and grapefruit in ozonated water. The Vermont Department of Agriculture is examining the potential of ozone to wash apples used in the apple cider industry.

Industrial gas-producing companies are developing mechanical systems for processing poultry that filter out biological waste material in poultry chiller water and then add ozone to disinfect the washwater

Consumer preferences may offer some insight about the acceptance of new products. Test market surveys by an independent marketing research firm in early 1998 indicated acceptance of ozonated foods when consumers are knowledgeable of various processing methods. Three food processing methods-- existing chlorine rinses, newly approved irradiation, and ozonation—were explained to consumers, who were then asked if they would purchase products treated by these methods *Eighty percent of consumers indicated a preference for products treated with ozone when given the choice of chlorine, irradiation, or ozone*

Food Storage

The use of ozone for food storage is believed to have started in 1909 when in the cold storage plant of cologne, the reduction in the germ count on the surface of meat stored there was observed after an ozone generator had been installed in the duct of fresh air used to ventilate the storage room.

Much more extensive examinations and experiments were required on the storage of fruits in cold storage plants in order to decide whether treatment by ozone could be deemed favorable or unfavorable because of the different requirements imposed on the storage of various fruits.

Although few publications or research reports have as yet become part of the public domain, the use of ozone is increasing in several major cold storage plants in Europe.

Van Laer and Troquet described, as early as 1928, the utilization of ozone in breweries. R.I. Tenny focused attention again 1972 on the possibilities for its use in the brewing industry. The technical shortcomings of the ozone generators in the 1940's were responsible for the setbacks encountered at the time.

Preservation

Practical operations for preservation start with the sterilization of air in such a way that air entering the storage room contain a sufficient amount of ozone to destroy microorganisms. At the same time, however, ozone decomposition to a significant extent is to be expected due to the high moisture content required, The walls of the storage room, the packaging materials, the absorption effect of the stored goods, and also to the oxidation reactions taking place.

These two requirements demand the most perfect distribution of ozonized air in the storage room and make it imperative that the capacity of the ozone generator ensures the maintenance of the appropriate ozone concentration throughout the whole mass of air. Otherwise it may happen that ozone will not reach the storage space properly, let alone the surface of the goods stored.

During storage, ozone exerts a threefold effect by destroying the microorganisms, oxidizing the odors and effecting the processes of metabolism.

Germicidal Effect

This effect of ozone has already been covered in general terms. For applications in the food industry, a greater emphasis should understandably be put on the changes in quality taking place following the ozone treatment, along with the specific effects exerted on individual products. The germicidal power of ozone is generally specific in respect of individual species.

It's primary action on molds is to suppress their growth and this effect can set in rapidly, particularly in the initial stage of a mold free surface. Afterwards, this process leads to the destruction of cultures already formed. Ozone attacks immediately the easily accessible cells on the surface since ozone exerts a surface effect in the first place and has an only slight depth of penetration.

Kolodyaznaya and Sponina investigated the micro flora causing the deterioration of the potato. Pure mold cultures of Fusarium Solani, Rhisoctonia Solani, and Phytophtora Solani were exposed to the action of ozone. From these species Fusarium Solani proved to be resistant to ozone. Ozonation applied for the storage of refrigerated meat destroys surface microorganisms, particularly the family of Pseudomonas responsible for spoilage

The Use of Ozone in Processing Plants

In all fish, poultry and red meat processing industries the problem of Salmonella and Listeria bacteria represents one of the biggest challenges. Frequent use of water to rinse and remove dirt and debris from the product, the work stations, floors, and walls is essential. Yet, most water supplies are contaminated, or treated with chlorine. Large amounts of chlorine are needed to kill bacteria in a short time available on the process conveyors. Unfortunately, chlorine also reacts with the meat, forming highly toxic and carcinogen compounds called THMs or Tri-Halomethanes. The color of the meat surface may also be degraded by chlorine, potentially rendering a lesser quality product. This is especially concerning when the rinse water stays in pockets inside the meat product.

Ozone comes closest to the *ideal* solution. Ozone has been used in this application for almost a hundred years. For decades, chlorine seemed to be a cheaper alternative. Only about two decades ago, massive research into the by-products of chlorine alerted the scientific world. It has been concluded that chlorine should ideally be eliminated not only from drinking water purification systems, but also from any application where organic materials are involved, and in the food processing industry in particular. Previously set dosages of chlorine are no longer effective on some viruses and parasites. For complete disinfecting much higher dosages would have to be used, but such levels are not allowable to contact the meat

Treatment of Beverage Waters

Soft drinks are produced regionally throughout the USA, using ray waters, which have widely differing qualities. Because of these diverse water quality discrepancies, when a standard syrup formulation is added, the resulting soft drink may not taste the same from bottling plant to bottling plant. Consequently, it is standard practice in this industry to pre-treat the raw waters, by essentially the same process, in attempts (usually quite successful) to produce standardized water qualities, which then will result in soft drinks which taste the same regardless of manufacturing location.

Currently, soft drink bottlers take water either from wells, or from municipal taps. When water is taken from municipal taps, it is first treated by superchlorination, to oxidize organics and remove all traces of chloramines (used by an increasing number of U.S. cites as the residual disinfectant). At the same time, lime is added (to lower alkalinity to below 50 mg/L as $CaCO_3$), and ferric chloride is added as a flocculating agent.

The chemically treated water then is filtered (sand) and passed through a granular activated carbon (GAC) filter to dechlorinate it and (ostensible) to remove halogenated organic materials formed during the superchlorination step. Purified water is sent to the process line for incorporation into soft drinks. GAC filters are steam reactivated monthly, in place.

When bottlers must use ground water, the dame treatment philosophy is employed, adjusting for the presence of iron, manganese, sulfides, and the absence of chloramine.

All soft drink bottlers in the U.S. are cognizant of the effects of chlorine on the tastes of soft drinks (hence the GAC filters used for declorination). Now they are becoming increasingly aware of the health detriments of chlorinated organic byproducts, which cannot be removed for long periods by the GAC filters. Consequently, the industry is looking seriously at ozone as a replacement for the pre-chlorinating step. Not only would ozonation eliminate the formation of chlorinated organic compounds, but GAC losses would be only a fraction of those currently experiences because chlorine pre-oxidation would be replaced by pre-oxidation with ozone.

Several bottlers currently are using ozone, not for treating their process waters, but for "sanitizing" the GAC filters. Over weekends, when the bottling lines are shut down and the plants are closed, the GAC filters are backwashed constantly with ozonized water in the mistaken belief that the ozone somehow kills the bacteria on the GAC particles. One plant, which this author has visited, used ozone solely for GAC "sanitizing". And management states that stream reactivation is required only one time per year, rather than monthly, without realizing that the concept is technologically impossible.

A second potential for ozone in soft drink bottling plants is for the sanitization of bottles prior to filling with the soft drink. The sanitizing properties of ozone are obtained nearly instantly, and no unwanted byproducts are produced. This application already is being practices in many European mineral water and soft drink bottling plants, and one West Coast bottler in the USA is known to have installed ozone for this specific application.

A third application is for sanitizing fill lines and vessels. These are treated with ozone-containing water after shift shutdown. The next morning, the lines are clean and safe to drain, as the ozone has disappeared.

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How Ozone Affects Bacteria, Fungus, Molds and Viruses

Ozone is a naturally occurring gas created from oxygen atoms. The oxygen molecule is made up of 2 oxygen atoms. These oxygen molecules are broken into atoms by the corona discharge during lightning storms or by UV light from the Sun. Single oxygen atoms cannot exist alone without regrouping back into di-atomic oxygen molecules. During this recombination stage some atoms will regroup into loosely bonded tri-atomic oxygen. This new molecule is called Ozone, as seen to the right (d = 1.28 A, Theta = 116.5^{o}). Due to the loose bond in this oxygen molecule – ozone is a very strong oxidant and an ideal chemical-free purification and a disinfecting agent.

Ozone is frequently misdiagnosed and equated to low-altitude pollution. Nothing could be farther from the truth. In fact, Ozone breaks down pollutants and should be welcomed when found in the air.

The most effective way to produce Ozone commercially is through the use of pulse injected corona discharge.

Disinfection by tri-atomic oxygen (Ozone) occurs through the rupture of the cell wall. This is a more efficient method than Chlorine, which depends upon diffusion into the cell protoplasm and inactivation of the enzymes. An ozone level of 0.4 ppm for 4 minutes has been shown to kill any bacteria, virus, mold and fungus. 1 parts per million is equivalent to: 8.345 pounds per million gallons (US).

When the effectiveness of Ozone as a disinfectant was measured, there was little or no disinfection up to a certain dosage. At higher levels the sanitizing effect increased greatly. For complete disinfection a surplus or residual Ozone has to be maintained in the solution to assure that every living microorganism has been contacted.

There has yet to be discovered any antibiotic that is truly effective in the virus arena. There are indications that DNA viruses such as Herpes are implicated in human cancers, since they organize the genetic material of the host cell to produce new viruses. Ozone will inactivate viruses on contact, even at very low residual concentrations. In case of polio, only 0.012 ppm removes all viral cells in less than 10 seconds.

Mold and mildew are easily controlled by Ozone present in air and in water. Giardia and Cryptosporidium cysts are susceptible to Ozone but not affected by normal levels of Chlorine.

The Effects of Ozone on Pathogens

The antipathogenic effects of ozone have been substantiated for several decades. Its killing action upon bacteria, viruses, fungi, and in many species of protozoa, serve as the basis for its increasing use in disinfecting municipal water supplies in cities worldwide.

Bacteria are microscopically small single-cell creatures having a primitive structure. They take up foodstuffs and release metabolic products, and multiply by division. The bacteria body is sealed by a relatively solid cell membrane. Their vital processes are controlled by a complex enzymatic system. Ozone interferes with the metabolism of bacterium cells, most likely through inhibiting and blocking the operation of the enzymatic control system. A sufficient amount of ozone breaks through the cell membrane, and this leads to the destruction of the bacteria.

Viruses are small, independent particles, built of crystals and macromolecules. Unlike bacteria, they multiply only within the host cell. Ozone destroys viruses by diffusing through the protein coat into the nucleic acid core, resulting in damage of the viral RNA. At higher concentrations, ozone destroys the capsid or exterior protein shell by oxidation.

Indicator bacteria in effluents, namely coliformas and pathogens such as Salmonella, show marked sensitivity to ozone inactivation. Other bacterial organisms susceptible to ozone's disinfecting properties include Streptococci, Shigella, legionella pneumophila, Pseudomonas aerunginosa, Yersinia enterocolitica, Campylobacter jejuni, Mycobacteria, Kelbsiella pneumonia, and Escherichia coli. Ozone destroys both aerobic and importantly, anaerobic bacteria which are mostly responsible for the devastating sequel of complicated infections, as exemplified by decubitus ulcers and gangrene.

The mechanisms of ozone bacterial destruction need to be further elucidated. It is known that the cell enveloped of bacteria are made of polysaccharides and proteins and that in

Gram negative organisms, fatty acid alkyl chains and helical lipoproteins are present. In acid-fast bacteria, such as Mycobacterium tuberculosis, on third to one half of the capsule is formed of complex lipids (esterified mycolic acid, in addition to normal fatty acids), and glycolipids (sulfolipids, lipopolysaccharides, mycosides, trehalose mycolates). The high lipid content of the cell walls of these ubiquitous bacteria may explain their sensitivity, and eventual demise, subsequent to ozone exposure. Ozone may also penetrate the cellular envelope, directly affecting cytoplasmic integrity, disrupting any one of numerous levels of its metabolic complexities.

Numerous families of viruses including poliovirus I and 2, human rotavruses, Norwalk virus, Parvoviruses, and Hepatitis A, B and non-A non-B©, among many others, are susceptible to the virucidal actions of ozone.

Most research efforts on ozone's virucidal effects have centered upon ozone's propensity to break apart lipid molecules at sites of multiple bond configuration. Indeed, once the lipid envelope of the virus is fragmented, its DNA or RNA core cannot survive.

Non-enveloped viruses (Adenoviridae, Picornaviridae, namely poliovirus, Coxsachie, Echovirus, Rhinovirus, Hepatitis A and E, and Reoviridae (Rotavirus), have also begun to be studied. Viruses that do not have an envelope are called "naked viruses." They are constituted of a nucleic acid core (made of DNA or RNA) and a nucleic acid coat, or capsid, made of protein. Ozone, however, aside from its well-recognized action upon unsaturated lipids, can also interact with certain proteins and their constituents, namely amino acids. Indeed, when ozone comes in contact with capsid proteins, protein hydroxides and protein hydroxides and protein hydroperoxides are formed.

Viruses have no protections against oxidative stress. Normal mammalian cells, on the other hand possess complex systems of enzymes (i.e., superoxide dismutase, catalase, peroxidase), which tend to ward off the nefarious effects of free radical species and oxidative challenge. It may thus be possible to treat infected tissues with ozone, respecting the homeostasis derived from their natural defenses, while neutralizing offending and attacking pathogen devoid of similar defenses.

The enveloped viruses are usually more sensitive to physico-chemical challenges than are naked virions. Although ozone's effects upon unsaturated lipids is one of its best documented biochemical action, ozone is know n to interact with proteins, carbohydrates, and nucleic acids. This becomes especially relevant when ozone inactivation of non-enveloped virions is considered.

Fungi families inhibited and destroyed by exposure to ozone include Candida, Aspergilus, Histoplasma, Actinomycoses, and Cryptococcus. The walls of fungi are multilayered and re composed of approximately 80% carbohydrates and 10% of proteins and glycoproteins. The presence of many disulfide bonds had been noted, making this a possible site for oxidative inactivation by ozone.

In all likelihood, however, ozone has the capacity to diffuse through the fungal wall into the organismic cytoplasm, thus disrupting cellular organelles.

Protozoan organisms disrupted by ozone include Giardia, Cryptosporidium, and free-living amoebas, namely Acanthamoeba, Hartmonella, and Negleria. The anit-protozoal action has yet to be elucidated.

Typical Dosage and Reaction Times

- Aspergillus Niger (black Mount): Destroyed by 1.5 to 2 mg/1.
- Bacillus Bacteria: Destroyed by 0.2 mg/1 within 30 seconds
- Bacillus Anthracis: Causes anthrax in sheep, cattle and pigs. A human pathogen. Ozone susceptible.
- Clostridium Bacteria: Ozone-Susceptible.
- Clostridium Botulinum Spores: Its toxin paralyzes the central nervous system, being a poison multiplying in food and meals. 0.4 to 0.5 mg/1.
- Diphtheria Pathogen: Destroyed by 1.5 to 2 mg/1.
- Eberth Bacillus (Typhus abdominalis): Destroyed by 1.5 to 2 mg/1.
- Echo Virus 29: This virus most sensitive to ozone. After a contact time of 1 Minute at 1 mg/1 of ozone, 99.999% killed.
- Escheriachia Coli Bacteria (from feces): Destroyed by 0.2 mg/1 within 30 seconds.
- Encephalomyocarditis Virus: Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/1.
- Enterovirus Virus: Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/1.
- GDVII Virus: Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/1.
- Herpes Virus: Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/1.
- Influenza Virus: 0.4 to 0.5 mg/1.
- Klebs-Loffler Virus: Destroyed by 1.5 to 2 mg/1.
- Poliomyelitis Virus: Kill of 99.999% with 0.3 to 0.4 mg/1 in 3 to 4 minutes.
- Proteus Bacteria: Very Susceptible.
- Pseudomonal Bacteria: Very Susceptible.
- Rhabdovirus Virus: Destroyed to zero level in less than 30 seconds.
- Salmonella Bacteria: Very Susceptible.
- Staphylococci: Destroyed by 1.5 to 2 mg/1.
- Stomatitis Virus: Destroyed to zero level in less than 30 seconds with 0.1 to 0.8 mg/1.

Streptococcus Bacteria: Destroyed by 0.2 mg/1 within 30 seconds

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Physical Benefits of Ozone

- Ozone is a faster acting oxidizing agent. Ozone is 350 times stronger than chlorine and 3000 times faster acting.
- Ozone has no chemical residual after treatment of agricultural commodities
- There is no storage of toxic chemicals required.
- Ozone is produced as needed, or on-demand.
- Ozone reduces the formation off-odors and off-flavors in treated products.
- Ozone eliminates off-odors in water or in storage environments.
- Excess ozone is easily destroyed via ozone destruct equipment.
- Ozone if effective in gaseous form, or as a dissolved gas in water (aqueous form).
- Ozone dosage is easy to control.

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Ozone as an Oxidizer

- Ozone is the alternative to traditional chemicals.
- Ozone is more effective than traditional chemicals without harmful by-products.
- Ozone kills all known Bacteria, Viruses, Cysts and Fungi (molds & yeast)
- Ozone oxidizes hydrogen sulfides, iron, and manganese.

Ozone Verses Chemicals

- Ozone is less dependent on the pH of the water, compared to other sanitizing chemicals.
- Gaseous ozone is extremely effective against aerobic microorganisms such as fungi (molds & yeasts).
- Ozone is a faster acting germicide, compared to other sanitizing agents.
- There is a broad range of germicidal activity; no microorganisms are spared.
- Ozone is the most effective single disinfectant against Cryptosporidium.
- Microorganisms do not become "resistant" to ozone.
- Ozone is not carcinogenic.

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UV Water Sterilization System

Sanitron™ Ultraviolet Purifiers utilize germicidal ultraviolet lamps that produce short wave radiation lethal to bacteria, viruses and other microorganisms present in water.

Economical and safe, **Sanitron™** Ultraviolet Purifiers offer rapid water treatment without the use of heat or dangerous chemicals - often for the lowest cost available by any means.

An ever-growing range of industries and consumer applications have found ultraviolet to be the ideal solution for their water treatment requirements.

Advantages of the Sanitron™ Water Purification Method

Effective - Virtually all microorganisms are susceptible to **Sanitron™** disinfection.
Economical - Hundreds of gallons can be purified for each penny of operating cost.
Safe - No danger of overdosing, no addition of dangerous chemicals.
Fast - Water is ready for use as soon as it leaves the purifier - no further contact time required.
Easy - Simple installation and maintenance. Compact units require minimum space.
Automatic - Continuous or intermittent disinfection without special attention or measurement.
Chemical Free - No chlorine taste or corrosion problems.
Versatile - Capacities available from two to thousands of gallons per minute (g.p.m.).

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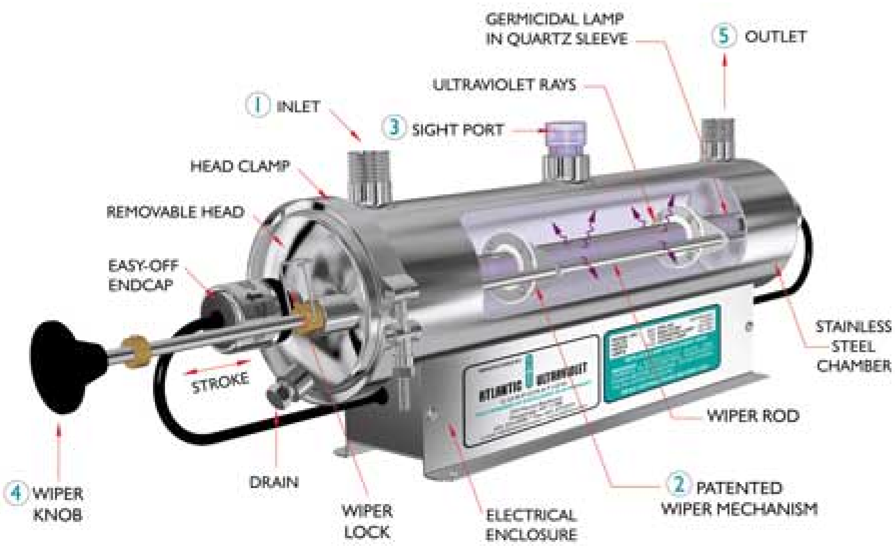
Principle of Operation for the Sanitron™ Water Purifiers



1. The water enters the purifier and flows into the annular space between the quartz sleeve and the outside chamber wall.
2. The wiper segments induce turbulence in the flowing liquid to assure uniform exposure of suspended micro-organisms to the lethal ultraviolet rays.
3. Translucent sight port provides positive indication of germicidal lamp operation.
4. The wiper assembly facilitates periodic cleaning of the quartz sleeve without any disassembly or interruption of purifier operation.
5. Water leaving the purifier is instantly ready for use.

Installation and Maintenance for the Sanitron™ Water Purifier

The purifier is installed as close as possible to the point of use. Connection of the inlet and outlet to the water supply and the plug into an ordinary electrical outlet is all that is required. Ordinary maintenance consists of cleaning the quartz sleeve with the manual wiper once monthly or more frequently where conditions dictate. Lamp replacement is recommended every 10,000 hours of operation (approximately 14 months of continuous service).

Germicidal Lamp Data

Lamp Number	Purifier Model No.	Nominal Lamp Length	Power (1) Consumption	Ultraviolet (2) Output	Rated Effective Life
05-1400	S14	8-15/16" (227mm)	10 Watts	2.3 Watts	10,000 Hrs.
05-1098	S17	11-7/8" (302mm)	14 Watts	3.7 Watts	10,000 Hrs.
05-1097	S23	17-3/4" (451mm)	20 Watts	6.4 Watts	10,000 Hrs.
05-1343	S37B	33-7/8" (860mm)	39 Watts	13.8 Watts	10,000 Hrs.

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Specifications for Sanitron™ Water Purifier Standard Models

Model	G.P.M.	G.P.H.	Inlet & Outlet Size[6]	Replacement Lamp	Power Consump[7]	Unit Dimension (inches)			Shipping Data	
						Length	Width	Height	Gross Wt.(lbs.)	Net Wt.(lbs.)
S14	2	120	1/2" NPT	05-1400	14 Watts	16-3/8	5-7/16	8-3/16	11	7
S17	3	180	3/4" NPT	05-1098	18 Watts	19-3/8	5-7/16	8-3/16	11	8
S23	6	360	3/4" NPT	05-1097	24 Watts	25-3/8	5-7/16	8-3/16	14	11
S37B	12	720	1" NPT	05-1343	44 Watts	39-3/8	5-7/16	9-1/2	30	20
S50B	20	1200	1-1/2" NPT	05-1334	54 Watts	52-3/8	5-7/16	9-1/2	36	29
S2400B	40	2400	2" NPT	05-1311	140 Watts	52-1/16	6-7/8	11-1/2	49	36
S5,000B[1]	83	5000	2" NPT	05-1311 (2 lamps)	280 Watts	52-1/16	7-1/4	15	116	85
S10,000B[2]	166	10000	2" NPT	05-1311 (4 lamps)	560 Watts	52-1/16	21	34-3/4	267	188
S15,000B[3]	250	15000	2" NPT	05-1311 (6 lamps)	840 Watts	52-1/16	21	53-17/64	400	263
S20,000B[4]	333	20000	2" NPT	05-1311 (8 lamps)	1120 Watts	52-1/16	21	71-49/64	534	396
S25,000B[5]	416	25000	2" NPT	05-1311 (10 lamps)	1400 Watts	52-1/16	21	90-17/64	670	520

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New & Improved Sanitron S2400B - S25,000B Now Available as S2400C - S25,000C which features:		
S2400C - S25,000C • Removable & Rotateable Heads • Type 316 Stainless Steel • Electropolished and Passivated inside and outside • UL Approved Ballasts ***Note: The specifications above for the S2400B - S25,000B apply to the S2400C - S25,000C***	This is new user-friendly, easy to install, flexible design allows for retrofitting into virtually all existing systems.	

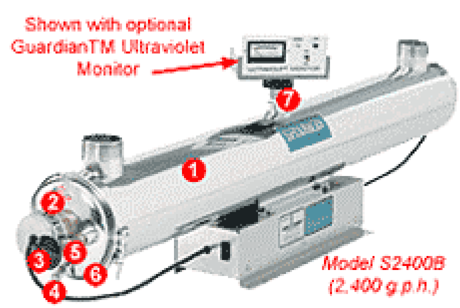
1. Two S2400B's connected in series, 1 inlet and 1 outlet.
2. Two S5,000B's connected in parallel, 2 inlets and 2 outlets.
3. Three S5,000B's connected in parallel, 3 inlets and 3 outlets.
4. Four S5,000B's connected in parallel, 4 inlets and 4 outlets.
5. Five S5,000B's connected in parallel, 5 inlets and 5 outlets.
6. All inlets and outlets are male pipe threads.
7. Total power consumption including ballast loss.

- Maximum recommended operating pressure for all purifiers is 100 p.s.i.
- Pressure drop at maximum recommended flow rate is less than 5 p.s.i.
- 120 Volt 60 Hz and 220 Volt 50 Hz units are standard.
- 12 and 24 Volt DC units also available.
- Sanitron™ is available for operation on public power supplied throughout the world.
- Consult factory with specific power requirements.

Sanitron™ Water Purifier Special Features

1 - Stainless Steel Construction Chamber, head and clamp are electropolished and passivated stainless steel for an attractive finish and dependable service.
2 - Quick Lamp Change Exclusive Easy-Off Retainer Cap™ enables effortless lamp replacement without shut down of water pressure or drainage of tank. No tools required.
3 - Patented Dual Action Wiper Mechanism Facilitates periodic cleaning of quartz sleeve without interruption of purifier operation. No disassembly required. Complies with U.S. Public Health Guidelines.

4 - Drain Plug Convenient, in-place drainage of purifier chamber.
5 - Wiper Lock Locks wiper mechanism in retracted position.
6 - Removable Flanged Head Units disassemble completely and easily in the event that repairs are necessary. No special tools or fixtures required.
7 - Sight Port Plug Visible glow provides positive indication of germicidal lamp operation. *(Unit shown with optional* **Guardian™ Ultraviolet Monitor** *in sight port)*.
(NOTE: FUSED QUARTZ SLEEVE - Insures optimum lamp output at normal potable water temperatures. See additional Optional Accessories by clicking on link on the top of this page)



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What is Ultraviolet Disinfection?

Ultraviolet (UV) light is invisible, electromagnetic energy with wavelengths between visible light and x-rays. UV light has long been acknowledged as a means of disinfection because of its ability to kill bacteria by penetrating their outer membrane and impairing proper DNA function. Wastewater disinfection with ultraviolet light is a process that has proven to be superior to other disinfection methods. Many micro-organisms are not easily inactivated by chlorine or ozone whereas relatively low UV will provide the level of disinfection required. Operation and maintenance is less costly and less time consuming with UV systems, as compared to other disinfection methods. UV eliminates storage, handling and transportation hazards associated with chemicals and gasses. Through the use of UV disinfection, it is possible to eliminate chlorine, its byproducts, and the need for dechlorination. When UV light is harnessed and properly transmitted, it provides a practical, safe and inexpensive means of water disinfection. This is achieved through the use of low pressure mercury vapor lamps generate UV radiation in wavelengths of 2537A (Angstrom) capable of destroying virtually all known forms of microorganisms and viruses.

How Does It Work?

Ultraviolet is that band of light located in the spectrum between 2000-3000A wavelength. The most effective germicidal range is at 2537A for destroying microorganisms, molds, spores, protozoa, virus and yeast. The intensity of ultraviolet is expressed in micro-watt seconds per square centimeter and is the product of the lamp output in watts, the length of time exposure and volume of water being treated microorganisms are destroyed with under 10,000 MW Sec./cm2.

Typical Example

Bacillus Anthracis	8700
Cholera	6500
Dysentery	4000
Infectious Hepatitis	8000
Typhoid Fever	4100
E Coli	7000
Legionella	7000
Pseudomonas	10500
Streptococcus	10000

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Factors to be considered in water or liquid purification

Ultraviolet Radiation: Ultraviolet (UV) light is invisible radiation within a range of the solar spectrum. UV is similar to the wave-lengths that are produced by visible light, but much shorter. UV radiation is measured in millionths of a millimeter, i.e., Angstrom units (one Angstrom unit wavelength equals one hundred-millionths of a centimeter), and like visible light, it primarily has a surface effect. Within the UV radiation spectrum, there are three main groups. Ultraviolet lamp radiation of 2537 Angstrom units (or 254 namometers) wavelength must hit the microorganism to inactivate it, and each microorganism must absorb a specific amount of energy to be destroyed. Proteins and nucleic acid, which all microorganisms contain as their main constituents, absorb UV radiation energy. After absorption, the UV energy destroys or inactivates the DNA (deoxyribonucleic acid), thus preventing the microorganisms from reproducing. Sterilization of water implies that all life, i.e. bacteria, mold virus, algae, and protozoa are destroyed. Table I gives the absolute amount of UV necessary to kill many of the common types. We can also supply an 1849A (185nm) UV lamp that produces ozone (03) disinfection residuals, and in most cases this lamp interchanges with our standard 2537A UV lamp. Complete sterilization is not necessary for the production of portable water. However, the water must conform with the drinking water standards of the Public Health Service or those of the agency governing your supply. Normally, the water must contain less than 2.2 coliforms per 100 ml to be considered safe to drink. The coliform group of microorganisms are generally associated with fecal matter and indicate that pathogenic (disease-causing) organisms, such as typhoid, may be present. As will be explained later, a different sizing formula must be used for purification if 100% sterilization is required.

Energy and Exposure

The germicidal spectrum of the ultraviolet wavelength is from 2000 to 3000 Angstroms, with the peak of 2537 Angstroms. The total UV energy emitted from all sides of the UV lamp is expressed in watts. The total exposure of the liquid is expressed in microwatt-seconds per square centimeter, which is a product of energy, time, and area. The same number of micro-watt seconds per square centimeter can be accomplished with a short exposure at a high intensity of UV or a long exposure at a low intensity of UV. Table II gives the UV energy data on the high intensity ultraviolet lamps used in purifiers.

Transmission

The amount of energy available to any microorganism from a given ultraviolet source is dependent on the UV transmission of the liquid. The transmission is dependent on the depth of the liquid and the absorption coefficient of the liquid. The absorption coefficient is dependent on the quantity and types of dissolved and suspended matter in the liquid.

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Generally, iron salts and organic matter have the greatest effect on absorption, while alkali salts (such as common salts) do not absorb these radiations. The physical requirements of less than 10 NTU of turbidity, 15 TCU of color, and 0.2 ppm of iron should be met before a water purifier is installed. Prefiltration of all suspended matter to at least 5 microns in size is recommended for all private water supplies, as the efficiency of the purifier is determined by the transmission of the water or liquid. Table III illustrates the percent of transmission of the ultraviolet for water of various absorption coefficients. The absorption coefficient of the average tap water varies between 0.12 and 0.07 with highly polished DI or distilled water at 0.008 and cloudy water from a private source, such as a pond, well, or spring, at 0.50 or less. The absorption coefficient of the liquid to be purified must be known for proper sizing.

Other Factors Affecting Ultraviolet Purification

The ultraviolet output of the UV lamp is also dependent upon the primary voltage output and the lamp wall temperature. Table IV shows the effect of line voltage on UV output, and Table V shows the effect of temperature. It will be noted that at 56.6F (12 C) the lamp will be only 22% efficient in generating bactericidal radiation. We use only high intensity UV lamps inside a high-transmission clear fused quartz jacket so that an optimum temperature of 104 F (40 C) can be obtained for 100% UV output. The liquid does not come in contact with the lamp. Another factor that must be considered is the useful life of the UV lamp. The performance of the various types of lamps is indicated in Table II. It is recommended that spare ultraviolet lamps be kept on hand at all times, and accurate records be kept of lamp use and replacement. The ultraviolet lamps output gradually decreases over the life of the lamp, and the lamp must be replaced as indicated by hours of use or by a UV monitor. Sizing of Ultraviolet Liquid Purification Equipment: The various factors that must be considered were discussed above. Assuming a proper voltage source, the purifier can be sized properly if the following are known.

(a) Peak flow rate required in gpm, gph, gpd or m3/h.
(b) Transmission and physical makeup (absorption coefficient) of the liquid to be treated.
(c) Ultraviolet energy level required for microorganism destruction (see Table I).

The Public Health Service requires that UV disinfection equipment have a minimum UV dosage of 16,000 uW sec./cm sq. (microwatt-seconds per square centimeter). All significant waterborne pathogenic microorganisms are destroyed by under 10,000 uW sec./cm sq. Industrial high purity water may require higher radiation levels depending on the type of microorganism to be destroyed. Suggested flow rates of the various models with different liquid transmission are indicated in figures 1 and 2. If 100% sterilization is required, the flow rate through the purifier can be computed, depending on the energy level required. For a particular problem or application, consult our technical staff.

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TABLE I	
Ultraviolet Energy Levels at 2537 Angstrom Units Wavelength required for 99.9% Destruction of Various Microorganisms UV Energy in Microwatt-seconds per Square Centimeter	
BACTERIA	
Agrobactrrium tumetaciens	8500
Bacillus anthracis	8700
Bacillus megaterium (vegetative)	2500
Bacillus megaterium (spores)	52000
Bacillus subtilis (vegetative)	11000
Bacillus subtilis (spores)	58000
Clostridium tetani	22000
Corynebacterium diphtheriae	6500
Escherichia coli	7000
Legionelia bozemanii	3500
Legionelia dumoffii	5500
Legionelia gormarii	4900
Legionelia micdadei	3100
Legionelia longbeachae	2900
Legionelia pneumophia	3800
Leptospira interrogans (infectious jaundice)	6000
Mycobacterium tuberculosis	10000
Neisseria catarrhalis	8500
Proteus vulgaris	6600
Pseudomonas aeruginosa (laboratory strain)	3900
Pseudomonas aeruginosa (envir. strain)	10500
Rhodospirillum rubrum.	6200
Salmonelia enteritidis	7600
Salmonelia paratyphi (enteric fever)	6100
Salmonelia typhimurium.	15200
Salmonelia typhosa (typhoid fever)	6000
Sarcina iutea	26400
SSerratia marcescens	6200
Shigelia dysenteriae (dysentery)	4200
Shigelia flexneri (dysentery)	3400
Shigelia sonnei	7000
Staphylococcus epidermidis	5800
Staphylococcus aureus	7000

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Staphylococcus faecalis	10000
Streptococcus hemolyticus	5500
Streptococcus iactis	8800
Veridans streptococci	3800
Vibrio cholerae	6500
MOLD SPORES	
Aspergillus flavus (yellowish green)	99000
Aspergillus glaucus (bluish green)	88000
Aspergillus niger (black)	330000
Mucor ramosissimus (white gray)	35200
Penicillum digitatum (olive)	88000
Penicillum expensum (olive)	22000
Penicillum roqueforti (green)	26400
Rhizopus nigricans (black)	220000
ALGAE	
Chlorelia vulgaris (algae)	22000
PROTOZOA	
Nematode eggs	92000
Paramecium	200000
VIRUSES	
Bacteriophage (E. coli)	6600
Hepatitis virus	8000
Influenza virus	6600
Pollo virus (Poliomyeiitis)	21000
Rota virus	24000
Tobacco masaic virus	440000
YEAST	
Baker's yeast	8800
Brewer's yeast	6600
Common yeast cake	13200
Saccharomyces var. ellipsoideus	13200
Saccharomyces sp	17600

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TABLE II

Technical Data on High Intensity Mercury Vapor Ultraviolet Lamps
Use for Air and Water Purification

Lamp No.	Lamp Length	Arc Length	Lamp Watts	Rated Life (HR)	UV Output (Watts)	Intensity (Microwatts per CM Sq.)***			
						Through Air		Through Water**	
						At 1"	At 3"	At 1"	At 3"
8060	17"	14"	16.0	9000	5.3	8800	3400	7040	3920
8090-OZ	17"	14"	16.0	9000	5.3	8800	3400	7040	3920
5340	33"	30"	39.0	9000	13.8	8800	3400	7040	3920
5360-OZ	33"	30"	39.0	9000	13.8	8800	3400	7040	3920
9410	61"	60"	65.0	9000	26.7	8800	3400	7040	3920
6780-OZ	61"	60"	65.0	9000	26.7	8800	3400	7040	3920

*Output of 2537 Angstroms with new lamps at 80 F, still air, ambient
**With an absorption coefficient of 0.10
***UV lamp intensity at 2537 Angstrom units wavelength at a given distance. Variations in voltage, temperature and tube material will cause the lamp output to vary. The intensity through water is based on a 0.10 absorption coefficient.

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TABLE III					
Relative percent output of 2537A for water absorption coefficients*					
Absorption Coefficient	Transmission		Absorption Coefficient	Transmission	
	At 1"	At 3"		At 1"	At 3"
0.008	99%	95%	0.12	75%	40%
0.02	95%	87%	0.15	72%	34%
0.03	92%	80%	0.16	70%	29%
0.04	90%	74%	0.17	68%	28%
0.05	88%	68%	0.18	65%	25%
0.06	87%	64%	0.20	60%	23%
0.07	85%	59%	0.25	56%	16%
0.08	82%	55%	0.30	54%	11%
0.09	81%	50%	0.35	50%	8%
0.10	80%	46%	0.40	40%	5%
0.11	78%	44%	0.50	30%	2%

TABLE IV	
Effect of line voltage on UV output, relative percent of 2537A*	
PRIMARY VOLTS	OUTPUT
90	68%
95	73%
100	78%
105	84%
110	90%
115	96%
120	102%
125	108%
*Optimum=118 VAC/60 HZ	

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TABLE V					
Relative percent output of 2537A radiation at various UV lamp temperature					
Temperature		Output	Temperature		Output
F°	C°		F°	C°	
56.6	12	22%	104.0	40	100%
60.8	16	30%	111.2	44	98%
68.0	20	40%	118.4	48	93%
75.2	24	53%	125.6	52	85%
82.4	28	68%	132.8	56	75%
89.6	32	85%	140.0	60	66%
96.8	36	95%	147.2	64	58%

Uses and Applications of UV Purifiers

Application	**Explanation**
Air conditioning and heating	10,15,16
Apple and fruit storage	5,16
Ampoules, bacteriological, biological enzyme laboratories	8,15,16
Bakeries, bread, cakes, pies, candy mfg.	1,2,8,15,16
Barber shops	16
Beverage plants (soft drinks), syrups, chocolate concentrates, flavoring extracts, coffee & tea concentrates, maple sugar & syrup, cider plants	1,2,3,6,8,15,16
Blood banks & donor agencies	1,8,15,16
Bottle water plants	1,4,8,15,16
Breweries	1,3,8,15,16
Butter processing	1,3,5,8,15,16
Canning	1,3,5,8,15,16
Cheese processing & packaging plants	1,3,5,8,15,16

Chicken, turkey and game farms	13,16
Cosmetics	1,2,3,8,15,16
Dairy products, ice cream	1,2,3,8,15,16
Drug & pharmaceutical mfgrs., vitamin products, chemical plants	1,2,3,8,15,16
Eggs, canned, frozen, dried	1,3,8,15,16
Electroplating & mirror plants	8,9,15,16
Electronic Equipment Manufacturing Plants	8
Farms	1,5,13,14,16
Food products, fruit juices, fresh/frozen	1,2,3,8,15,16
Homes	12,13
Hospitals, sanitoria, institutions, nursing & convalescent homes	1,2,3,8,10,12,13,14,15,16
Hotels, motels and camps	12,13,16
Meat packing, fish and other food plants	1,3,5,11,13,16
Mines, lumber camps, oil refineries	8,10,13,14,15,16
Nylon & synthetic fiber manufacturers	1,6,8
Office and factory	13,16
Paper mills	1,8,10,15,16
Packaging	1,3,5,13,16
Photograph film and paper manufacturers	8,10,15,16
Potable water treatment plants	13,16
Rest Rooms	13,16
Restaurants	12
Schools, auditoriums, theaters, public buildings, office buildings, factories	1,3,11,13,15,16
Sewage plants	3,8,10,13,14,15,16
Swimming Pools	14,16
Vegetable washing	1,5,15,16

EXPLANATIONS (List of applications for water or liquid purifiers)

1. Purify final rinse water in holding and blending tanks, cans, bottles, pipe lines, heat exchanges and all other types of equipment and containers, floors, walls, tables and other working areas, to flush out foreign matter and disinfecting solutions without introducing water-borne bacteria which may re-contaminate the surface or product.
2. To provide uncontaminated water for making simple (sugar) syrup so as to avoid fermentation and costly spoilage. Also for making various other aqueous solutions in which bacteria contamination would cause spoilage.
3. To provide germ-free make-up water used to reconstitute powered milk; to add to syrups for carbonated or still beverages, or to add other ingredients where a percentage of water is present in the end product. Thus, by eliminating micro-organisms, the purity, freshness and flavor of the products are safeguarded and shelf life is extended.
4. To purify the bottle spring, well or other water prior to bottling, to destroy invisible algae and all types of microorganisms which would otherwise cause obnoxious odors, tasts, and cloudiness. This eliminates costly returns, loss of customers and sales, by safeguarding the purity, freshness and tastes.
5. Sterilize wash water for butter, cottage cheese and all other curd cheeses, smoked meats and other foods without introducing water-borne contaminants which later develop unsightly mold, foreign odors and taste, reduce butter-score and result in losses.
6. Special purifiers are available for treating susceptible liquids, including pharmaceuticals, liquid sugar, chemicals, various solutions and wines, to destroy budding yeast cells, bacteria, mold and algae so as to prevent fermentation and other spoilage. Any micro-watt seconds per square centimeter intensity can be delivered.
7. To use in the preparation of yeast culture, to prevent contamination of pedigreed yeast, to assure consistent,

pedigreed quality, unaltered flavor and safeguarding of purity, freshness and keeping qualities; also in the preparation of any unprocessed products containing water.

8. Eliminate slime and fouling of mineral beds inall types of water treatment equipment. It prevents frequent shutdown for de-contamination procedures and provides the best, and most economical, method of obtaining bacteria-free, de-ionized water. The first chamber purifies the water before it enters the de-ionizer, this prevents bacteria, mold, yeast or algae settling on the resins. The second chamber irradiates the water after it leaves the de-ionizer to assure purified water in the event of internal contamination from the resins.
9. As a final, germ-free rinse for flushing electronic and other parts, without introducing contamination which may later cause fouling or product loss.
10. Purify cooling water for heat exchangers, etc., also spray-washing water and process water recirculated for other purposes. To eliminate odors, contamination from water-borne bacteria, algae, slime, etc., & prevent algae build-up in pipe lines, cooling towers & clogged spray nozzles.
11. To provide germ-free water for making ice incorporated in frankfurters, bologna and other smoked meats, also in other foods and beverages.
12. To provide germ-free water for recirculation in swimming pools with a reduction of up to 80% of chlorine and other chemical previously required. This means that the extremely small amount of chlorine recommended is at an unobjectionable level where it is also easy to maintain, and swimming is a pleasure. This small amount of chlorine acts as a bleach-booster to maintain the water crystal clear, while the ultra-violet purifier is constantly discharging germ-free water into the pool. An algaecide should be used periodically to prevent any microscopic spores from adhering to the sides and bottom of the pool, preventing them from entering the U.V. purifier, where they are destroyed.
13. To deliver purified, germ-free water by guaranteed 99% bacteria destruction in water distribution systems without the use of chlorine and without imparting any foreign taste, odor, corrosive or allergenic properties to the water. Cost of processing is the world's lowest - up to 30,000 GPH purified for only one kilowatt of current - costing only pennies a day!
14. To bacteriologically purify the final clear effluent, without the

use of chlorine, from sewage treatment equipment or plants. At least 99% bacterial destruction is accomplished at high flow rates. The high cost of chlorinators, chemicals, supervision and constant testing are eliminated at a substantial savings.

15. To destroy at least 99% of all organisms in the water and sewage effluent from food, beverage, pharmaceutical plants, abattoirs, public conveyors, planes, ships, etc., after the water is rendered relatively free of turbidity, solids and excess color.

16. A) Permanent or portable ultra violet ozone fixtures for mold, bacteria and odor control.
B) *Direct U.V. radiation* with permanent handing hood or wall mounted fixtures or portable U.V. air purifiers for sterilization of air, surfaces or products. To prevent air-borne bacteria or mold contamination on foods, meats, vegetables, fruits, products, tables, walls, wrappers, packages, cans, bottles, ovens, coolers, caps, etc., shielding used for human and animal protection from direct U.V. radiation.
C) *Indirect U.V. radiation* with ceiling or wall fixtures to sterilize the room air and eliminate the spread of air-borne infections among humans and animals. Safe for humans and animal occupancy due to special construction. No protective clothing, face masks or shields required unless placed below eye level. Proven effective in hospital rooms, operating rooms, nurseries, offices, cafeterias, restaurants, schools, motels, hotels, hallways, coolers, holding rooms, stables, pens, incubators, hatcheries, brooder rooms, laying houses and veterinaries.
D) Direct and indirect radiation in special shielded cabinet for the sterilization of glasses, cans, utensils, instruments, caps, bottles, containers, conveyor belts, fillers and processing equipment. Special fixtures and cabinets for special applications.
E) High intensity germicidal radiation fixture for air conditioning and heating system ducts for 98% destruction of air-borne bacteria and communicable diseases. Special equipment for odor control. Prevents the dangers of drawing in bacteria and germs in a closed system...heating or cooling them and redistributing them to other rooms or areas. Proven effective in hospitals, nurseries, offices, restaurants, schools, etc.

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General Information on Ultraviolet Purification

1. The peak germicidal wavelength of the ultra-violet spectrum is 2537 angstrom and its intensity is expressed as micro-watts per square centimeter, a product of energy and area, or micro-watt seconds per square centimeters, a product of energy, time and area. Germicidal ultra-violet is invisible to the human eye.
2. Germicidal ultra-violet must contact the micro-organisms to kill them. Therefore, the water or liquid must be clear to be purified, and a prefilter is recommended if the water does not meet USPHS physical standards and chemical requirements.
3. Humans and animals must be protected from direct radiation of ultra-violet lamps, however, can safely congregate in areas or rooms treated with indirect radiation. Special shields are not required. Ultra-violet will not penetrate through glass or plastic and regular eye glasses are sufficient protection for looking at the bare ultra-violet lamp for a short period of time.
4. The 1849 angstrom wavelength of the ultra-violet from our special ozone lamps produces activated oxygen in free air (0_3) and (H_2O_2) hydrogen peroxide in water. This is commonly referred to as OZONE and is an excellent odor oxidizer and bactericide. Ozone can be used to supplement the 2537 A. wavelength on hard to get places. Safe for humans and animal if used as directed.
5. All ultra-violet lamps have a useful operating life expressed in hours, and must be replaced as directed for effective results. We manufacture U.V. Monitors for the measurement and metering of ultra-violet germicidal radiation output.

Micro-Organism	**Disease**	**MW Sec./CM2**
Salmonella typhosa	Typhoid fever	4,100
Salmonella paratyphi	Enteric fever	6,100
Shigella disenteriae	Dysentery	4,200
Shigella flexneri	Dysentery	3,400
Vibro comma	Cholera	Approx. 6,500 (2)
Leptospira spp.	Infectious jaundice	6,000 (2)
Poliovirus	Poliomyelitis	Approx. 6,000 (3)
Virus of infectious hepatitis	Infectious hepatitis	Less than (8,000) (4)

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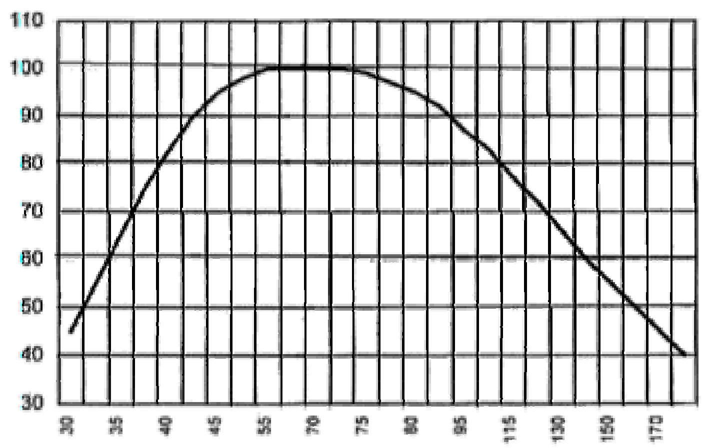
Our purifiers provide in excess of 30,000 MW sec/cm2 of ultra-violet energy.

General Notes

1. Angstrom unit: A unit of wavelength 1/1,000,000,000 of a centimeter.
2. This estimate is based on the similarity of these organisms to others and is probably of the same order of magnitude.
3. Based on American Journal of Hygiene (1951) Dic, G.W. 53:131
4. Since viruses in general are more susceptible to U.V. radiation than bacteria, this estimate is based upon work done with bacteriaophage.

UV Lamp Output Relative to Reactor Water Temperature

Relative Percentage Output



Water Temperature Degrees F

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