SELF-CLEANING FILTRATION FOR PRE-TREATMENT OF MEMBRANE, UV AND OZONE WATER TREATMENT SYSTEMS

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Recent field data has shown the effectiveness of automatic self-cleaning filters in removing suspended solids down to less than 3 microns in size without flocculents, pre-coats or granulated media. Pre-treatment of ozone systems is often needed to remove organic solids that would utilize high amounts of ozone during oxidation leaving little for complete disinfection. Self-cleaning screen filters can physically remove much of that organic matter efficiently and economically resulting in the need for lower ozone concentrations. The use of ultraviolet light water treatment has been growing rapidly. An effective job of disinfection requires that microorganisms be directly exposed to light of the appropriate wavelength. If suspended particles of sufficient size are present, shadowing can protect microorganisms from inactivating doses of ultraviolet light. Self-cleaning filters remove the likelihood of shadowing. Tests conducted over many days have demonstrated the removal of particles 10-micron and larger from raw lake-water prior to UV treatment. The ratio of water needed in cleaning the screen to process water varied between 0.31% and 0.40%. Membrane systems of differing types (micro, ultra, nano, RO) require different degrees of pre-filtration. Self-cleaning screen filters with weavewire elements down to 10 microns are available for most membrane pre-treatment applications while recently developed "thread filtration" technology can remove suspended solids down to below 3 microns for reverse osmosis systems. One application of pre-filtration for RO at a coal fired power plant in Nevada showed raw water from a well to have TSS = 10.5 ppm. Laboratory analyses of the particle size distribution after a 10-micron screen filter showed 99% removal of particles 5 micron and larger. Screen filtration of canal water using a 10-micron weavewire screen showed a TSS reduction of 97% in California. Use of a thread filter in Newfoundland has given substantial cryptosporidium removal at a municipal water treatment plant. These examples and others demonstrate the successful and dependable use of automatic self-cleaning mechanical screen and thread filters for suspended solids removal well below the visible limit of the naked eye.

INTRODUCTION

There are four generally recognized methods of water disinfection. The most widely used is oxidizing biocides such as chlorine. These oxidizers kill microorganisms chemically by destroying the cell's interior enzyme group. The second method is ozone, which oxidizes the cell walls of microorganisms. This method also effectively removes color, odor and taste from water. Distillation makes up the third method of disinfection where pure water is vaporized and re-condensed as microbe-free water. The fourth method is the use of ultraviolet (UV) light to inactivate living pathogens by preventing reproduction.

OZONE SYSTEMS

The traditional use of chlorine for disinfection of water in the US has recently come under scrutiny because of the concern over disinfection by-products (DBPs), especially trihalomethanes (THMs). Current studies have also shown *Giardia* and *Cryptosporidium* oocysts to both be very resistant to chlorine.[1] Ozone, on the other hand, is very effective for inactivating both *Giardia* and *Cryptosporidium* oocysts. Only fluorine is stronger than ozone as an oxidizing agent. Ozone has 152 percent of the oxidizing potential of chlorine. It can also be more than a thousand times faster than chlorine in killing *E.coli* and many other pathogenic microorganisms.[2] Ozone (from the Greek word "ozein" meaning "to smell" referring to the characteristic odor of ozone) has several advantages over other chemical methods of disinfection:[3]

- Ozone can be generated on-site as needed eliminating the chance of sudden spills or large releases;
- Ozone rapidly decomposes to simple oxygen, leaving behind no residuals or toxic substances;
- Ozone is effective at lower doses than chlorine and adds no chemical taste or odor to the water;
- Ozone reactions produce no halogenated compounds;
- Ozone acts more rapidly, and more completely than do other common disinfecting agents;
- Ozone reacts swiftly and effectively on *all* strains of viruses.

Because ozone is so unstable and leaves no residual, contact times are difficult to determine. Therefore, the less extraneous organic matter in the form of suspended particles, the more available the ozone dosage is for inactivating pathogens. This leads to defining the proper pre-treatment for ozone systems. The removal of suspended solids, whether organic or inorganic, can be accomplished by various well-proven methods. Granular media filters, screen filters, cartridge filters, bag filters, drum filters, flocculation/clarification systems, membranes, centrifuges, filter presses, belt filters and vacuum filters are a few of those available. All will remove suspended solids but at varying costs and efficiencies. Automatic self-cleaning weavewire screen filters are often the most reliable and cost-effective forms of filtration for the removal of suspended solids.

ULTRAVIOLET SYSTEMS

Ultraviolet light (UV) uses high-energy light (typically a wavelength of 254 nm) to penetrate an organism's cytoplasmic membrane then shifts electrons scrambling the DNA structure preventing microorganisms from reproducing.[4] The actual inactivation process is the fusing of Thyamine bonds within the DNA strand preventing the DNA strand from replicating during the reproduction process.[5] Some advantages of UV include:

- Disinfection occurs without chemicals;
- There is no danger of over-treatment;
- There are no residuals nor disinfection by-products;
- Physical and chemical properties of the water are not altered;
- UV equipment is easily added to any new or existing water system;

UV energy of 10,000 microwatt-seconds per square centimeter (μw-sec/cm^2) will destroy most bacteria, viruses and yeast. US government officials recommend a minimum dosage of 16,000 μw-sec/cm^2 for disinfection of filtered water. However, UV has little effect on *Giardia* and *Cryptosporidium* oocycts. Dosages between 6,500 and 8,000 μw-sec/cm^2 have been shown to cause 99.9% destruction of fecal coliform, *E.coli*, cholera, influenza and hepatitis.[6] Pre-treatment is generally required prior to UV equipment. Table 1 shows the maximum recommended concentration levels of various influent constituents.

Recommended Maximum Concentration Levels Before Ultraviolet Influent for Standard Applications[7]		
Turbidity	5 NTU	Maximum
Suspended Solids	10 mg/l	Maximum
Color	15 APHA units	Maximum
Iron	0.3 ppm	Maximum
Manganese	0.05 mg/l	Maximum
pH	6.5-9.5	Maximum
Hardness	5 grains	Maximum
Hydrogen Sulfide	0.5 ppm	Maximum

Table 1

Turbidity is an important parameter because the very nature of UV activity depends upon transmittance levels. Historically, a minimum UV transmittance of 50% has been accepted for disinfection purposes. Suspended solids affect UV disinfection in two ways. Suspended solids tend to block UV light thus reducing transmittance levels. Secondly, the "shadow effect" makes particles behave like protective shields for microorganisms, occluding them from the inactivating rays of UV energy. Suspended particles of <10 microns in size provide little hindrance to UV disinfection. UV light can penetrate water completely when suspended particles are 10 to 40 microns in size but additional UV demand is required. All particles larger than 40 microns must be removed to assure complete UV light penetration. Pre-filtration of water is necessary to allow UV systems to work effectively. Automatic self-cleaning mechanical filters are very effective in meeting this challenge.

MEMBRANE SYSTEMS

Membranes or, more properly, semi-permeable membranes are thin layers of polymers with pores ranging in size from 0.1 micrometers (microns or μm) for microfiltration to <0.0001 micron for reverse osmosis. In its simplest, though not complete, form a membrane is a sieve with very small holes. Materials removed from a liquid stream by membranes are particulates (suspended solids), dissolved organics (molecules and proteins), microorganisms (protozoan cysts, bacteria, virus), and dissolved inorganics (ions).

There are many good books and articles on membrane technology available for the reader who wants a more thorough treatise on the subject than can be given here. However, one thing is common to all membranes, they will eventually foul causing a decrease in flow through the membrane and requiring cleaning. The objective of pre-treatment is to extend the time between membrane cleanings as much as possible while still maintaining the integrity of the membrane itself. The type of pre-treatment must be determined specifically for each case but removal of particulates (suspended solids) is almost always a necessity. Automatic self-cleaning mechanical filters alone or in conjunction with other components can usually provide sufficient cost-effective particulate removal. Refer to Table 2 for more on membrane selection.

COMPARISON OF MEMBRANE TECHNOLOGIES[8]

Feature	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Pore Size (µm)	0.1-1.0	0.001-0.01	0.0001-0.001	<0.0001
Operating Pressure (psi)	<30	20-100	50-300	225-1000
Suspended Solids Removal	Yes	Yes	Yes	Yes
Dissolved Organics Removal	Yes	Yes	Yes	Yes
Dissolved Inorganics Removal	None	Yes	Yes	Yes
Concentration Capabilities	High	High	Moderate	Moderate
Energy Usage	Low	Low	Low-Moderate	Moderate
Membrane Stability	High	High	Moderate	Moderate
Recommended Pre-Filtration (µm)	500-200	100-50	25-10 followed by 5-1 µm cartridge	10-5 followed by 5-1 µm cartridge
Operating Costs ($/1000 gal)	.50-1.00	.50-1.00	.75-1.50	1.50-5.00

Table 2

AUTOMATIC SELF-CLEANING SCREEN FILTER OPERATION

Unfiltered water flows into the filter through the inlet flange of the filter body as shown in Figure 1. Water then proceeds through the multi-layer cylindrical stainless steel weavewire filter element (screen) from the inside out causing particulates larger than the filtration degree (pore size) of the screen to accumulate on its inside surface. When a 7-psi pressure differential is reached across the screen due to debris build-up, the filter begins a cleaning cycle. During the cleaning cycle, there is no interruption of flow downstream of the filter. The filter operation and cleaning cycle is controlled and monitored by a Programmable Logic Control (PLC).

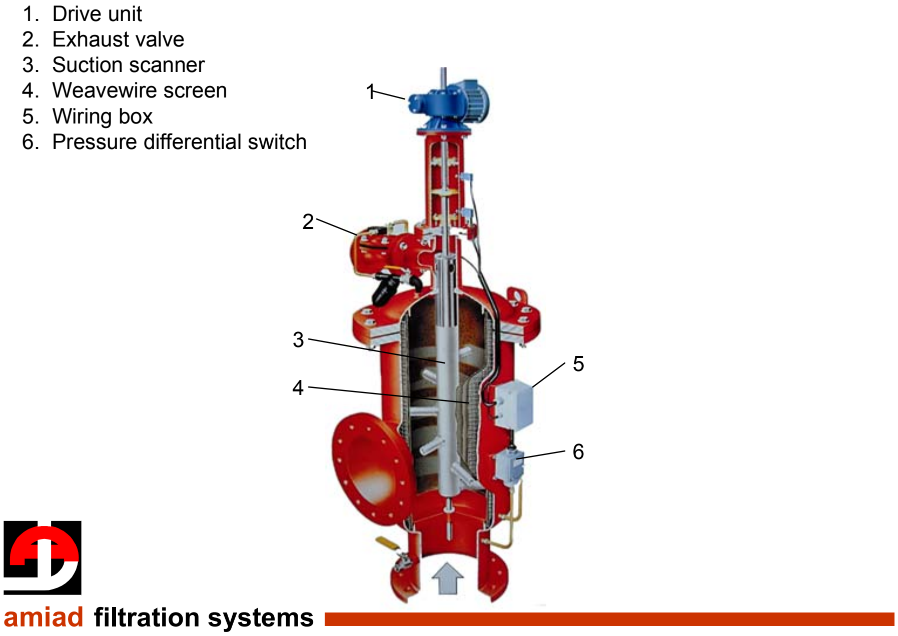

Figure 1

During the cleaning cycle a device called a suction scanner rotates and moves linearly inside the cylindrical screen. A valve opens connecting the inside of the suction scanner to atmosphere. Nozzles branch from the central tube of the suction scanner with openings only a few millimeters from the screen surface. The differential gauge pressure between the water inside the filter body (35-150 psig) and the atmosphere (0 psig) outside the filter body creates high suction forces at the openings of each of the suction scanner nozzles. This suction force causes water to flow backward through the screen in a small area at each nozzle pulling the filter cake off the screen and sucking it into the suction scanner and out the exhaust valve to waste. The electric driving mechanism then rotates the suction scanner at a slow, fixed rotation while simultaneously moving the scanner linearly at a fixed speed. The combination of rotation and linear movement gives each suction scanner nozzle a spiral path along the inside surface of the filter screen. The cleaning cycle is completed in 10 to 40 seconds depending on filter model, during which time the nozzles remove the captured debris from the entire filtration area of the filter screen. A more detailed explanation of the operation of this type filter can be found in the paper SELF-CLEANING PRE-FILTRATION FOR R.O. AND OTHER MEMBRANE SYSTEMS.[9]

AUTOMATIC SELF-CLEANING THREAD FILTER APPLICATION

The thread filter has a number of effluent collection tubes inside a steel vessel. Attached to these collection tubes are numerous flat cassettes, about the size of playing cards, wound tightly with layers of textile thread. A flat plate with ridges lies at the center of each cassette between the thread windings. Raw water is fed into the filter vessel. The water then passes slowly through the layers of thread into the collection tubes at very low velocity. Large particles are trapped on the surface of the thread cassettes by simple surface filtration much like a screen. Smaller particles begin to pass between the surface threads but become trapped by interception, impingement, entwinement and adhesion. This technology is much more involved than the simple mechanics of a screen filter. Since several mechanisms are at play in stopping suspended particles and because of the very nature of the system, it is difficult to determine the exact filtration degree of the filter except to note extensive data shows it to be in the 3-micron range. The pressure differential initiated cleaning cycle is quite unique. The filter must be taken off-line during the cleaning cycle. Two models of the thread filter are available with the smaller (45 gpm flow rate) taking only 25 seconds to complete a cleaning cycle. The larger unit (800-1000 gpm flow rate) must be taken off-line for up to 10 minutes for each cleaning cycle. During the cleaning cycle the filter is drained. A high-pressure pump mounted on the filter shoots a fine high-pressure stream onto the cassettes from a nozzle that passes back and forth over the array of cassettes. This fine stream passes right through the thread windings and hits the ridged plate inside each cassette. The water splashes off this plate causing many droplets to pass back out of the cassette through the threads in the opposite direction of filtration flow. These droplets carry and knock particles out of the thread windings where they are then drained out of the filter vessel. The filter vessel is then filled with influent and placed back on-line. Another feature of this technology is that the filter can operate on pressures anywhere from 3 to 150 psi. Typical applications include pathogen removal, drinking water treatment, turbidity control, swimming pool filtration, membrane protection and cooling systems.

APPLICATION 1

A public utilities district draws water from a mountain lake and utilizes a UV system for disinfection. The local Public Health Service determined that 10-micron filtration was needed to prevent suspended particles from shielding pathogens from the inactivation of UV rays. Parameters for the system are:

- Flow Rate: 1600 gpm to expand to 2400 gpm in 2 years
- Min. Pressure: 50 psi
- Max. Pressure: 80 psi
- Water Temp.: 50°F ±2°
- Water Intake: 30 ft. below surface and 1800 ft. from shoreline
- Filtration Degree: 10-microns
- Debris: Organic particles

Particles 10-micron and larger are removed successfully by the installed filters with many smaller particles also removed by the filter cake. No quantification of the removal of particles smaller than 10 microns has been determined to-date. Data collected shows that the flush water going to waste during cleaning cycles is between 0.31 and 0.40% of the effluent discharged from the filters.

APPLICATION 2

Automatic self-cleaning screen filters are used by a water treatment facility in the state of Washington as pre-treatment for a membrane system. The filters remove both organic and inorganic particulates to prevent repeated fouling of the membranes. Parameters are:

- Flow Rate: 4900 gpm (7 MGD) to expand to 7000 gpm (10 MGD)
- Pressure: 52 psi
- Water Source: Lake
- Delivery System: 10 miles of 28" pipe
- Filtration Degree: 500-microns

The pre-filtration system provides better-than-expected protection for the membrane system. The filters go through a cleaning cycle every three hours based on a timer with a pressure differential switch as a back-up. Water going to waste for cleaning the screens is less than 0.03% of the effluent discharged from the filters.

APPLICATION 3

A municipality in Newfoundland, Canada needed to remove *Cryptosporidium* oocysts from lake water before disinfection in their water treatment plant. A thread filter was installed two years ago with proven dependability. Tests showed 98% removal of *Cryptosporidium* oocysts. Last year a second thread filter was installed in series with the first and *Cryptosporidium* oocyst removal increased to greater than 99%. This does not meet the US standard of 3-log removal of all 1-micron particles but greatly assists the drinking water treatment process.

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