Self-Cleaning Filters for Pre-Treatment of Membrane and UV Water Treatment Systems

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ABSTRACT: The removal of suspended solids is necessary to protect membrane systems and prevent the "shadow effect" in ultraviolet (UV) treatment systems. 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 flocculants, pre-coats or granulated media. Tests have demonstrated the complete removal of particles 10 micrometers (also microns or µm) and larger with self-cleaning weavewire screen filters and particles 3 microns and larger with thread filter technology.

INTRODUCTION

There are three generally recognized methods of chemically disinfecting water. The most widely used is oxidizing agents such as chlorine. An oxidizer kills microorganisms chemically by destroying the cell's interior enzyme group. The second method is ozonation. Water is dosed with ozone gas that oxidizes the cell walls of microorganisms rendering them inactive. This method also effectively removes color, odor and taste from water due to organic and inorganic compounds. The third method is the use of ultraviolet (UV) light to inactivate living pathogens by interfering with reproduction.

Two other methods of disinfection are by physical means. Distillation makes up the first method where pure water is vaporized and then condensed as microbe-free water. However, the potential exists for volatile organic compounds to be vaporized and condensed along with the water. The second physical method is membrane filtration, a process of extremely fine surface filtration that must overcome the natural osmotic potential of the water solution.

This report will investigate the pre-treatment of one chemical and one physical means of water treatment.

ULTRAVIOLET LIGHT - Ultraviolet light (UV) uses high-energy light (typically wavelengths near 254 nm) to penetrate an organism's cytoplasmic membrane. This energy then shifts electrons scrambling the DNA structure preventing microorganisms from reproducing.[1] The actual inactivation process is the fusing of Thymine bonds within the DNA strand preventing the DNA strand from replicating during the reproduction process.[2] Some advantages of UV include:

- Disinfection occurs without chemicals;
- There is no danger of over-treatment;
- There are no residuals or 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 lamblia* and c*ryptosporidium* 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.

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 micron 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). Because of the infinitesimally small entities dealt with in this technology, blinding of the membrane surface becomes a chronic problem. To maintain the efficiency of this technology, pre-treatment must remove the greater bulk of the suspended solids to allow the membranes to efficiently remove selected dissolved solids. One to five-micron bag and cartridge pre-filters have traditionally been used to treat the influent to membrane systems. The inherent nature of the elements in these pre-filters has restricted them to one-time use then being discarded and replaced by new elements. Under many conditions these pre-filter elements may be useful only for a few hours before replacement. This replacement activity can be very labor-intensive and quite expensive. A very cost saving alternative is the use of automatic self-cleaning filters to remove the bulk of the suspended solids. These filters remove all suspended solids above 3 microns and many particles down to one micron in size. They may utilize either a weavewire screen mesh woven from 316-L stainless steel or thread-wound cartridges. Such filters have programmable logic controllers (PLC) and automatically clean themselves based on a preset pressure differential between the inlet and outlet. Units with a footprint of four square feet are capable of filtering hundreds of gallons per minute. A great advantage of the self-cleaning screen filter technology is that filtered water is continuously supplied to the downstream treatment system even during the twenty-second cleaning cycle without duplicity

SELF-CLEANING FILTERS

SCREEN FILTER - European technology perfected the weaving of fine stainless steel wires into a screen with close tolerance openings of 10 microns in 1996. This paved the way for self-cleaning automatic screen filters to operate as pre-filters for membrane and ultraviolet water treatment systems. These filters can now remove all contaminants 10 microns in size and larger and many particles down to 1 micron or even less under some circumstances.

Self-cleaning mechanical screen filters are easier to maintain and operate than granular media filters, have a much smaller footprint for a given flow rate, utilize less energy and use 40-80% less flush water for a given flow rate. Also, there is no possibility of media carryover. This type of mechanical screen filter does not stop filtering during the cleaning cycle so redundancy is not required to provide a constant supply of pre-filtered water.

Filter Operation – Figure 1 shows an example cutaway of a self-cleaning mechanical screen filter. Unfiltered water enters the inlet flange at the bottom of the filter body. The water passes into the cylindrical screen element made of 316L stainless steel, through the screen and out the side outlet flange. Macro particles (debris) are captured on the inside surface of the screen and build a filter cake. As this cake builds, a pressure differential develops across the screen. A pressure differential switch (PDS) constantly compares the pressure inside and outside of the screen element. When a preset pressure differential is reached (usually 5 to 7 psi), the PDS signals the PLC that it is time to begin a cleaning cycle. The PLC first opens the hydraulic diaphragm exhaust valve to atmospheric pressure. This valve is connected to the hollow 316 stainless steel suction scanner that has nozzles with end openings within a few millimeters of the screen surface. The pressure differential at each nozzle hole, caused by the difference between the working gauge pressure (35-150 psi) and atmospheric gauge pressure (0 psi), results in a small low-pressure area in the vicinity of each nozzle. This low pressure causes water to flow backward through the screen in this small area pulling the filter cake off the screen and sucking it into the suction scanner and out the exhaust valve to waste. While this is taking place, the PLC starts the electric drive unit that slowly rotates the suction scanner at a speed that will not disturb the filter cake except where it is being sucked into the scanner at the nozzles. At the same time, the suction scanner is moved linearly between two limit switches by a threaded shaft and fixed nut assembly. This gives each suction scanner nozzle a spiral motion such that the entire screen surface is sucked clean by the scanner in 12-40 seconds depending upon the filter model. When the upper limit switch is reached, signaling that every square inch of the screen has been covered by nozzles, the PLC checks with the PDS to see that the pressure drop across the screen is less than 1 psi. If so, the PLC closes the exhaust valve and stops the drive unit and the system waits for the next 5 - 7 psi pressure drop across the screen to occur. If the pressure differential across the screen is greater than 1 psi the cleaning cycle will repeat itself. This will continue as needed or until the PLC program signals a fault and carries out a preprogrammed function, i.e. turns on a warning light, stops a pump, opens a by-pass, etc.

This cleaning method results in thorough cleaning of the screen element during each cleaning cycle, minimum pressure drop through the system and uninterrupted filtration. Macro particles are removed from the fluid and sent, along with a small volume of carrier water, to a wastewater drain, fluid recovery system or surface water source (lake, pond, river, ocean, etc.). This simple cleaning system uses one slow moving part (suction scanner) and one hydraulically operated diaphragm valve. Wear and maintenance are minimal. The heavy-duty four ply 316L stainless steel screens are typically replaced only when the filtration degree requires changing. The polyester coating on the filter body provides a high degree of protection. All 316 stainless steel bodies are available in critical situations and a rubber coating can be applied during the manufacturing process allowing the filter to be used in seawater applications. Total water volume wasted is dependent upon the TSS concentration and the filtration degree of the screen. This volume is typically much less than 1% of the total flow through the strainer.

THREAD FILTER – A more recent filter technology has availed itself to pre-treatment applications where filtration degrees down to 3 microns and below are required. The thread filter combines the proven technologies of surface filtration and depth filtration into an efficient and reliable system.

<u>Filter Operation</u> - 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 polyester thread. A flat plate with ridges lies at the center of each cassette

1. Drive unit
2. Exhaust valve
3. Suction scanner
4. Weavewire screen
5. Wiring box
6. Pressure differential switch

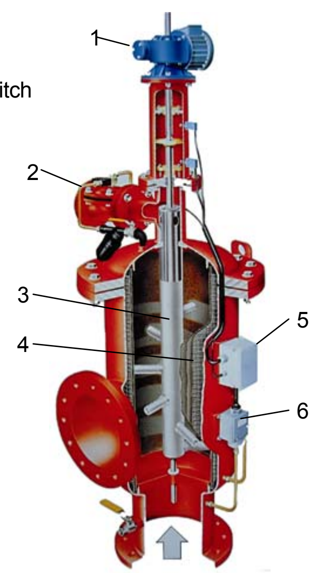

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Figure 1. Self-Cleaning Filter

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, entanglement 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 that extensive data shows it to be in the 3-micron and below 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.

APPLICATIONS

ULTRAVIOLET PRE-TREATMENT – 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: 50ºF ±2º
- Water Intake: 30 ft. below surface and 1800 ft. from shoreline
- Filtration Degree: 10-microns
- Debris: Organic particles

The installed filters remove particles 10-micron and larger successfully 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.

MEMBRANE PRE-TREATMENT – Most membrane applications, whether microfiltration, ultrafiltration, nanofiltration or RO, require some form of pre-treatment to remove the bulk of suspended solids.

Membrane Case One - In August 1996, a sand media pre-filtration system was replaced at a coal fired utility plant near Las Vegas, NV with a self-cleaning mechanical screen filter. The utility had experienced too much sand carryover from the media filters. One-micron cartridge filters are located between the pre-filter and the RO membrane system. The flow rate is 250 gpm passing through the self-cleaning mechanical screen filter with a 10-micron screen. The raw water source is a well with a TSS concentration of 10.46 ppm. The filter effluent maintains TSS values of 2.5 ppm giving a TSS reduction of 76%. Laboratory studies have shown 99% removal of all particles over 5 microns in size and 86% removal of all 1 micron particles. SDI values after the pre-filter have run consistently below 3.0. This self-cleaning mechanical screen pre-filter has been performed flawlessly for six years.

Membrane Case Two - A coal fired utility plant in eastern Wyoming receives water from a reservoir. Originally the water was passed through a bank of carbon media filters followed by 10-micron bag filters and 5-micron cartridge filters before reaching the RO membranes. The cartridge filters were plugging repeatedly with TSS passing through the media and bag filters and also with periodic episodes of carbon carryover from the media filters. In March 1998 a self-cleaning mechanical screen filter was installed with a 10-micron screen to replace the 10-micron bag filters. A flow rate of 800 gpm passes through the system with a TSS concentration of 0.49 ppm delivered to the mechanical screen filter from the bank of carbon media filters. Effluent leaves the self-cleaning mechanical screen filter at 0.04 ppm for a TSS reduction of 92%. Carbon media upsets have had no effect on the RO membranes since installation of the self-cleaning screen filter.

Membrane Case Three - A glass manufacturing facility in Ontario, CAN was utilizing water from Lake Huron by passing it through a 5-micron cartridge before entering an RO system. The only pre-treatment before the cartridge was chlorination. The 5-micron cartridges not only plugged very quickly, but they did not provide enough protection to the RO membranes causing the membranes to need cleaning about three times more frequently than originally stated by the RO system manufacturer. Two self-cleaning mechanical 10-micron screen filters were installed in parallel as pre-treatment to the cartridge filters. The cartridges were then changed from 5 microns to 1-micron ratings. Tests show that in the particle size range of 15 - 30 microns, the 10-micron screen removes all particles as expected. In the 5 -15 micron particle sizes, TSS was reduced by 63%. Even particles in the size range of 1 - 5 microns show TSS reductions of 36%.

Membrane Case Four - A pilot test was set up at a utility plant in California in 1998 to test the TSS reduction by a self-cleaning mechanical screen filter on raw canal water. The San Joaquin River feeds the canal. The 10-micron filter received water from the canal with a TSS concentration of 2.51 ppm. The TSS concentration in the effluent from the filter was 0.08 ppm for a TSS reduction of 97%.

Membrane Case Five - 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) in the near future
- 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 PDS as a back-up. Water going to waste for cleaning the screens is less than 0.03% of the effluent discharged from the filters.

PARASITE REMOVAL - 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* oocysts removal increased to greater than 99%.

SUMMARY

Fully automatic self-cleaning filters provide an economical means of removing suspended solids down to below 3 microns from water streams. The efficient suction scanning principle of self-cleaning screen filters allows the filter cake to be removed completely from the screen surface within seconds without physically touching the cake or screen. During the suction scanning cleaning cycle the filtration process is uninterrupted; thereby, providing filtered water downstream at all times, eliminating the need for duplex systems. Due to their proven record of long-life, wide range of filtration degrees and low maintenance, self-cleaning screen filters lend themselves to pre-treatment of UV and membrane water treatment systems in many industrial, commercial and municipal applications. Self-cleaning thread filters are not only a very competitive pre-treatment system for the removal of suspended solids but also for the control of serious parasites such as *cryptosporidium* and *giardia lamblia*. Self-cleaning filters make wise replacements for granular media filters. They also extend the life, performance and efficiency of fine bag or cartridge filters lowering capital and operational costs to membrane and UV pre-treatment.

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