

THE EFFICIENT REMOVAL OF ORGANIC AND INORGANIC SUSPENDED SOLIDS – OLD PROBLEM, NEW TECHNOLOGY

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ABSTRACT

The Romans used sand as a filter media to treat their drinking water 2000 years ago. Centuries ago water was poured through layers of cloth to remove visible impurities in drinking water with fabric bags and paper cartridges soon following. Darcy employed sand beds in Dijon, France over 200 years ago to conduct his experiments for developing his famous equation to describe fluid flow through a porous medium. Since ancient times man has observed that water left quiescent for a period of time becomes clarified, and thus *clarifiers* were born. For millennia, man has known that certain visible impurities were displeasing in drinking water with entities invisible to the naked eye and harmful to health making their way known with the invention of the microscope. About one hundred years ago the practice of disinfection began. Soon to follow were treatments of softening, deionization, reverse osmosis and other membrane technologies and now we are looking at the removal of radiation and naturally occurring toxic elements. The future will assuredly hold many other treatment technologies. However, the need to remove suspended solids as a pretreatment step will always be necessary for surface and reuse-water sources. A very cost saving alternative to present-day pretreatment clarifiers and sand filters is the use of automatic self-cleaning screen filters to remove a large portion of the suspended solids before traditional water treatment systems receive the raw water. These filters present an impassable barrier to any particle larger than the filtration degree selected for each particular case. And because the differential pressure across the screen is kept to a low maximum level, particles can be hard inorganic in nature or soft organics. This type of filter utilizes a weavewire screen woven from 316-L stainless steel. Such filters are PLC controlled and automatically clean themselves based on a preset differential pressure threshold across the screen. Units with a footprint of four square feet are capable of filtering thousands of gallons per minute. Because there is only one moving part during the short cleaning cycle and no mechanism comes in contact with the screen element, maintenance and repairs are minimal. Installation requires only bringing power to the filter unit and bolting the filter's inlet and outlet flanges into the piping system. No pneumatic or hydraulic lines are required. Another great advantage of this technology is the fact that filtered water is continuously supplied to the downstream system even during the twelve to thirty second cleaning cycle, without redundant filter units. Self-cleaning pre-filtration drastically reduces the operational costs of water treatment systems giving the treatment process constant water quality year-round even from seasonally varying rivers and streams.

TERMS AND DEFINITIONS

Filtration: The term *filtration* can be defined in its simplest form as the process of removing solid particles from a fluid (liquid or gas) by forcing the fluid through a porous medium through

which the solid particles cannot pass. The filtration spectrum divides solid particle sizes into five segments ranging from sub-molecular ions to macro particles as shown in Table 1.

RANGE	SIZE	EXAMPLES
Ionic	<0.001 micron	Ca ⁺ , Cl ⁻ , Fe ⁺⁺ , Na ⁺
Molecular	0.001 - 0.1 micron	Sugar, Virus, Gelatin
Macro-Molecular	0.1 – 1 micron	Tobacco Smoke, Bacteria
Micro-Particular	1 – 10 micron	Red Blood Cells, Flour
Macro-Particular	10 – 3500 micron	Pollen, Beach Sand, GAC

Table 1: Filtration Spectrum

Filtration Degree: The smallest particle size requiring removal from the fluid stream in a specific application is called the *filtration degree*. Two conventions are used to define filtration degree. One is taken from the textile industry referring to the density of threads expressed as the number of threads per linear inch. This definition uses the term "mesh" to describe the filtration degree. In the field of filtration the term has come to mean the number of pores or openings per linear inch in a woven media. Although still in common use, the term "mesh" is not a true parameter of measurement since the actual opening or pore size of such a medium depends on the diameter of the threads or wires and the type of weave used in the manufacturing process. The second convention used to describe *nominal* filtration degree, preferred in the municipal and industrial arenas, is an actual linear dimension of the *shortest* straight-line distance (length or width) across an individual opening or pore of the filter medium. This is most often given in microns; i.e. 1/1000 of a millimeter or 0.00004 of an inch. The *absolute* filtration degree is the length of the *longest* straight-line distance across an individual opening of the filter medium.

Effective Filtration Area: The total area of the filter medium that is exposed to fluid flow and is usable for the filtration process is referred to as the *effective filtration area*. Any structural member or other solid barrier that prevents fluid flow and particle separation from occurring over any surface area of the filter medium, such as structural supports, is not included in the effective filtration area.

Filtration Open Area: Another important definition needed when comparing filters and filtration methods is the *filtration open area*. This is the pore area or sum of all the areas of all the holes in the filter medium through which the fluid can pass. Filtration open area is often expressed as a percentage of the effective filtration area. The type of filter medium can affect this greatly as shown in Table 2.

FILTRATION DEGREE	FILTRATION OPEN AREA	
	WEAVE WIRE	WEDGE WIRE
500 micron	43%	33%
200 micron	37%	13.3%
100 micron	32%	6.6%

Table 2: Filtration Open Area

Water quality consists of a multitude of parameters, some relevant to filtration and many of no consequence. These parameters can be divided into two basic aspects, chemical and physical. Of primary concern in the filtration process are certain physical parameters with a few chemical parameters as possible secondary concerns.

Total Suspended Solids (TSS): Particle load or *total suspended solids* (TSS) is of major concern in filtration and is best defined as the concentration of total solid particles above the molecular range given in milligrams per liter (mg/L) or parts per million (ppm). This alone offers limited help in the design of filtration systems.

Particle Size Distribution (PSD): If along with TSS the *particle size distribution* (PSD) is known, the concentration (or volume) of particles removed from the fluid by a filter is readily determined for a given filtration degree. PSD is given in particle counts (particle density) per size unit, usually in one-micron increments. PSD can also be given in percent volume of TSS (volume density) per size unit. The latter means of expressing PSD is much more useful in designing macro filtration systems.

Clogging Factors: Those elements that cause a filter or strainer to lose hydraulic capacity are referred to as *clogging factors* and can be divided into organic and inorganic segments. Organic clogging factors include all phyto-plankton such as algae and some bacteria, zooplankton like protozoa and small crustaceans, and animal and vegetal detritus. Typical inorganic factors include sand, silt, clay, metal shavings, pipe scale and rust flakes. The degree of difficulty for removing these clogging factors from a filter varies considerably, not only from factor to factor, but from filter medium to filter medium.

FILTRATION METHODS

The terms "filtration" and "straining" are used synonymously in this paper. However, the term straining is usually reserved for removing larger solid particles from a fluid while filtration can mean the removal of any size particle. The methods of filtration addressed in this paper are those most commonly used to remove macro-particles (>10 microns) from a liquid stream; therefore, the terms "straining" and "strainers" will be used often. Such methods are used in industrial, agricultural and municipal water systems. Each specific application should be evaluated independently to design the most appropriate filtration system. Macro-filtration can be classified into three distinct mechanisms. These are kinetic, surface and contact filtration.

Kinetic Filtration: The cyclonic type separator best exemplifies *kinetic filtration* or separation. This mechanism utilizes the dynamic physical forces of angular acceleration, linear velocity, and specific gravity differentials to remove a percentage of the various macro-particles present in the raw fluid stream. This type of separation requires the solid particles to have a specific gravity appreciably greater than that of the fluid.

Surface Filtration: *Surface filtration* is a sieving process utilizing a medium such as a screen element to present a two dimensional physical barrier to particles too large to pass through its

holes or openings. The Amiad automatic self-cleaning screen filters described below adhere to this filtration mechanism.

Contact Filtration: Filters utilizing granular media represent *contact filtration*. Suspended solids in the fluid stream are held within the media by impingement and adhesion on the surface of media granules and entrapment between media granules. The long-standing sand filter is a classic example of a contact filter.

BACK FLUSHING VERSUS FORCED BACK FLUSHING (Suction Scanning)

Figure 1 shows a two-dimensional schematic of a simplistic screen strainer with body housing, inlet, outlet and screen media. As dirty water enters the strainer, particles larger than the filtration degree are trapped on the screen surface. These large particles start acting as a filter aid and begin trapping smaller and smaller particles. Eventually this layer of particles, called a filter cake, will cause enough pressure or hydraulic loss across the filtration area that some cleaning method must be employed.

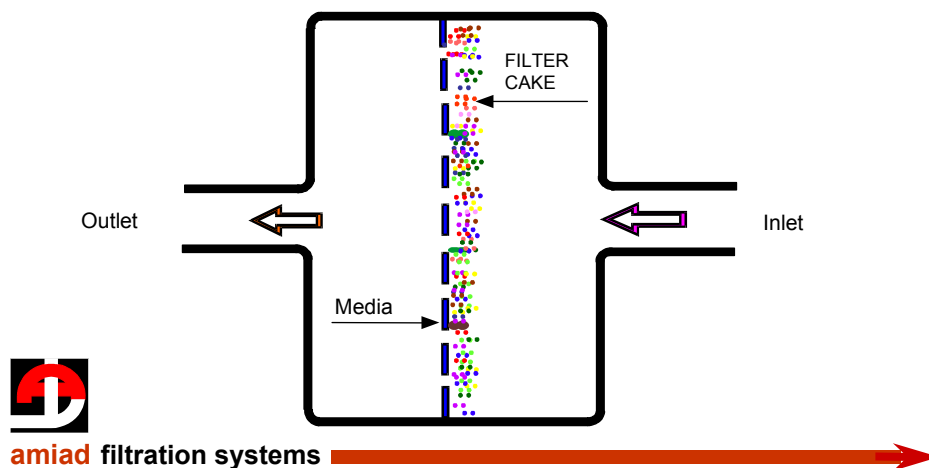


Figure 1: Simply Screen Strainer

As an example, an 8" Amiad Model EBS strainer with a filtration degree of 100 microns has an inlet cross sectional area of 50 square inches and an outlet cross sectional area of 50 square inches. However, the open area of the screen (sum of the areas of holes) in this strainer is 500 square inches. If we simple back flush the strainer by reversing the flow we get the situation shown in Figure 2.

Once 50 square inches of the filter open area is cleaned, the fluid velocity through the inlet, outlet and cleaned screen area will be equal. Therefore, there is no energy available to clean the remaining 450 square inches of filter open area. The screen remains 90% blocked yet the differential pressure across the screen is zero. No amount of back flushing will clean more than 10% (50 square inches) of the screen in this example. This results in the fallacy of cleaning screen strainers by simple back flushing methods.

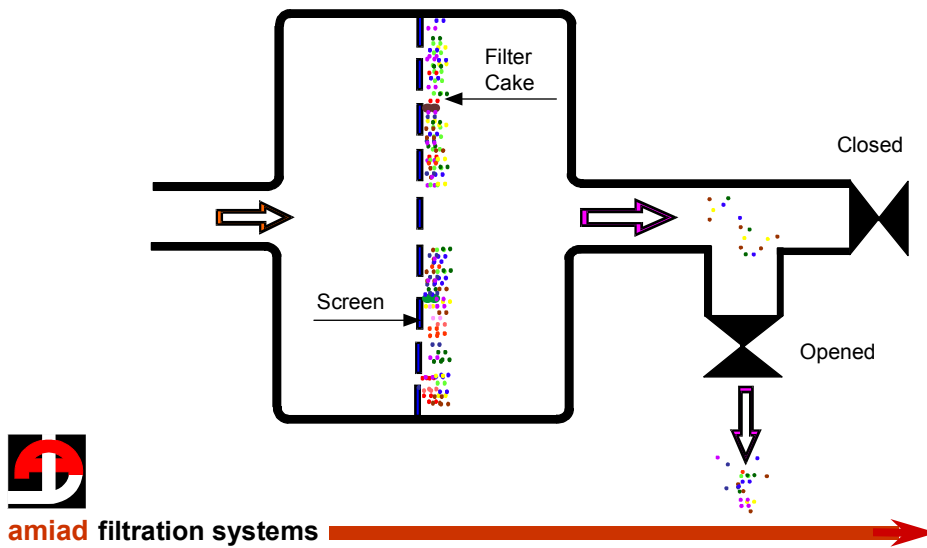


Figure 2: Strainer Back Flushing

Again, taking the simple strainer of Figure 1, let us apply *forced back flushing* to the screen as shown in Figure 3.

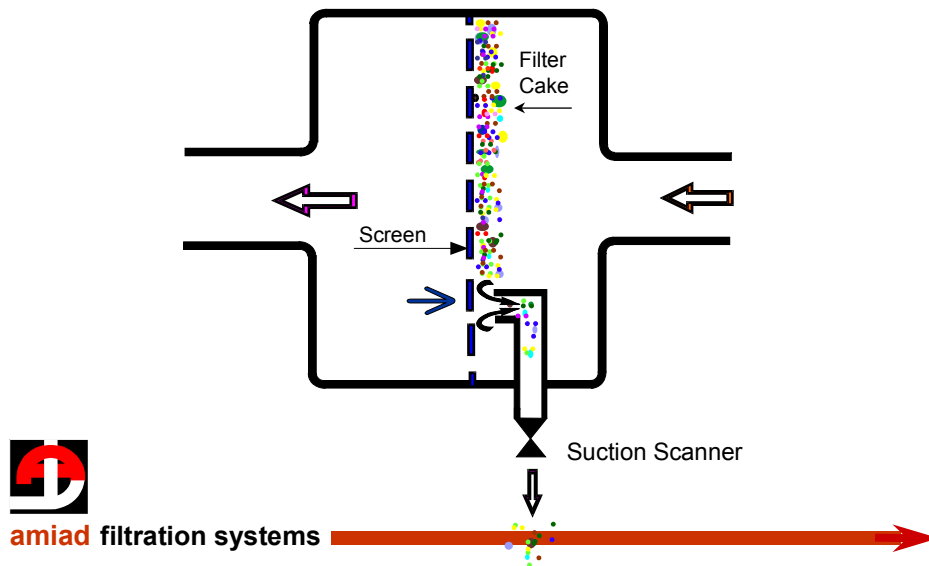


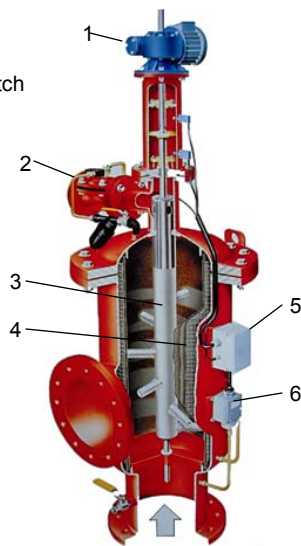
Figure 3: Forced Back Flushing

A device called a *suction scanner* is used to limit the cleaning of the screen to a small confined area. The suction scanner is nothing more than a hollow tube with one end very close to the screen surface and the other end exposed to the atmosphere. The differential pressure between the inside of the strainer body (the fluid working pressure) and atmospheric pressure (zero gauge pressure) creates a tremendous suction in a small area near the screen surface. The filter cake (trapped debris) is quickly sucked off the screen and expelled to the atmosphere. The suction scanner is then moved across the entire surface of the screen in less than one minute to remove all debris from the screen. In the meantime, the filtration process continues without interruption.

OPERATION OF THE AMIAD SELF-CLEANING STRAINER

Figure 4 shows a cutaway of an Amiad Model EBS strainer utilizing the suction scanning method of screen cleaning.

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



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Figure 4: Amiad Model EBS Automatic Strainer

Dirty water enters the inlet flange at the bottom of the strainer housing. 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, the fluid pressure drops across the screen. A pressure differential switch constantly compares the pressures on both sides of the screen element. When a preset differential pressure is reached (usually 7 psi), the differential pressure switch signals the programmable logic controller (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 openings in the ends very close to the screen surface. The differential pressure 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 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 at about 50 feet per second 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, a threaded shaft passing through a fixed nut moves the suction scanner linearly between two limit switches. This gives each suction scanner nozzle a spiral motion such that the entire screen surface is sucked clean by the scanner in 12-30 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 pressure differential switch to see that the differential pressure has dropped across the screen element. If so, the PLC closes the exhaust valve, the drive unit stops, and the system waits for the next 7-psi pressure drop across the screen to occur. If the pressure differential across the screen has not

dropped, the cleaning cycle will repeat itself. This will continue as needed or until the PLC program signals a fault after a preset time duration 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 housing provides a high degree of protection. Housings made entirely of 316 stainless steel are available in critical situations. Rubber coatings can be applied to carbon steel housings during the manufacturing process allowing the filters 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.

Amiad weavewire 316L stainless steel screens are strong and long lasting, capable of withstanding a 250-psi pressure differential across the screen with no distortion. Filtration degrees are available from 500 microns down to 10 microns. Macro particles typically removed by Amiad self-cleaning suction scanning strainers include sand, silt, pollen, insects, fibers, pipe scale, rust flakes, algae, metal fines, metal hydroxides, vegetable matter, weld balls, sealer, plastic chips and all life forms of zebra mussels including their eggs and veligers, to mention a few. They are found in industries such as automotive, foundry, mining, irrigation, food, pulp & paper, plastics, municipal water supply, wastewater treatment and even penguin ponds at the zoo.

Municipalities are finding the Amiad self-cleaning strainer to be the economical choice for pre-treatment of surface water sources. The Amiad strainer removes early season sand and silts resulting from snow melt and spring rains. The Amiad strainer easily removes algae and other organics caused by late summer blooms. The result is consistent water quality delivered to the municipal water treatment plant all year round at a fraction of the cost of flocculation and sedimentation pre-treatment systems.

Municipal, industrial and commercial wastewater treatment facilities that cannot discharge effluent year-round are finding Amiad self-cleaning strainers allow them to stay within regulatory limits. Effluents stored in holding ponds accumulate algae, bird feathers, turtles, fish, wind-blown debris and other suspended solids. Though once of discharge quality, the effluent discharged from these ponds often cannot meet the daily solids load limit imposed by regulatory agencies. A small pump and Amiad strainer can solve this problem very economically.

The Amiad self-cleaning strainer coupled with a 10-micron stainless steel weavewire screen can pre-filter potable water down to a level ready for most membrane systems. Some companies using this approach state they are getting an average 5-micron nominal filtration and go directly to RO membranes. Others feel more comfortable installing a cartridge filter between the Amiad strainer and the membrane to polish the influent. Either way, Amiad strainers provide a fully

automatic self-cleaning system to remove all or nearly all of the suspended solids that would cause havoc with typical membrane systems.

Self-cleaning mechanical screen filters offer advantages over traditional multi media filters on several fronts:

- Capital costs are generally 30-60% lower for self-cleaning mechanical screen filters.
- Installation costs are much less for mechanical screen filters since no concrete pad is required and the piping itself usually supports the filter.
- Self-cleaning mechanical screen filters use 40-60% less water for cleaning than typical granular media filters.
- Energy requirements are reduced for self-cleaning mechanical screen filters that operate between 1-8 psi pressure loss across the filter compared to 6-12 psi pressure losses across a granular media filter.
- The cleaning cycle of a mechanical screen filter is usually <5% as long as that required by granular media filters for the same flow rate. This means less pressure and flow fluctuations downstream.
- Self-cleaning mechanical filters have no media to degrade or carryover.

Self-cleaning mechanical screen filters may or may not meet the SDI requirements for membrane system pre-filtration. This depends upon the physical parameters of the suspended solids in the feed water. However, self-cleaning mechanical screen filters can remove the solids down to less than 10-microns that tend to prematurely plug finer bag and cartridge filters. These finer filters will, in turn, provide water with acceptable SDI values. Self-cleaning mechanical screen 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 pre-filtration.

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 inactivation by 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

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.

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 glass manufacturing facility in Ontario, Canada was utilizing water from Lake Huron by passing it through a 5-micron cartridge before entering an R.O. 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 R.O. membranes causing the membranes to need cleaning about three times more frequently than originally stated by the R.O 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-micron to 1-micron. Tests results are self-explanatory as shown in Table 3.

Particle Size (microns)	Influent TSS (ppm)	Effluent TSS (ppm)	TSS Reduction
1-5	0.11	0.07	36%
5-15	0.56	0.21	63%
15-30	0.36	0	100%
1-30	1.03	0.28	73%

Table 3: Application 3 Data

SUMMARY

Amiad fully automatic self-cleaning strainers provide an economical means of removing suspended solids down to 10 microns from water streams. The efficient suction scanning principle 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 of the strainer 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, Amiad automatic self-cleaning filters lend themselves to many uses in industrial, commercial and municipal markets.

ACKNOWLEDGEMENTS

Technical Staff, Amiad Filtration Systems, Oxnard, CA

Tom Hamilton, Power Products & Services Company, Battle Ground, WA