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Fundamentals and Advantages of Screen Filtration

Introduction

The "art" of filtration utilizes many methods for separating solid particles from fluids. There is often no right or wrong method. Water quality and customer requirements usually determine the "best" method for each unique situation. Ridged screens, pleated cartridges, string wound cartridges, melt blown cartridges, woven fabrics, non woven fabrics, sintered metals, granular media, frizzy balls and membranes are just some of the types of filters available today. This plethora of filter types are often employed to do the same thing - remove suspended solids from a stream of water. All aspects of the many types of filters available cannot be addressed in this forum. Therefore, this manuscript will concentrate on only screen filters and their properties. Aside from all the advantages of screen filtration, one of the biggest hindrances to their use is their tendency to clog quickly and need for frequent manual cleaning. There are many automatic and semi-automatic methods available to minimize or even eliminate the need for labor when cleaning the permanent screens in this class of filter. Screen filters can be stand-alone equipment or can be pretreatment for other methods of removing finer solids down to the size of ions. With openings as large as 2", such as bar screens at wastewater treatment plants, to openings as small as 10 microns, screen filters can be used for a wide variety of applications when properly applied.

Terms and Definitions

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 are too large to pass. Straining or sieving are terms often associated with this process. Typical solid particles found in screen filtration applications may include coarse sands and pipe scale thousands of microns in diameter to pollens, silts and algae which may be ten microns or less in size. *Macro-filtration* refers to the removal of particles greater than about 10 microns in size. Therefore, most screen filters perform macro-filtration.

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. The first is taken from the textile industry. In that industry the density of a woven material is expressed as the number of threads per linear inch referred to as "mesh." In the field of filtration the term mesh has come to mean the number of *pores or openings* per linear inch in the screen media. Although still in common use, the term "mesh" is not a true parameter of measurement since the actual opening or pore size depends on the diameter of the threads or wires and the type of weave used in the screen manufacturing process. The second and more preferred convention used to describe *nominal* filtration degree is an actual linear dimension of the shortest 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 millimeter or 0.00004 inches. The *absolute* filtration degree is often defined as the length of the longest straight line distance across an individual opening of the filter medium.

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 is not included in the *effective filtration area*. This parameter is very important when comparing different makes and models of filters.

There are two basic types of screens in the industry. The first is called *wedge-wire* screen and is formed by laying stainless steel wires, having trapezoidal shaped cross-sections, parallel to one another with a small gap between them. The openings therefore are long slots with the width of the slot the nominal filtration degree as shown in Figure 1.

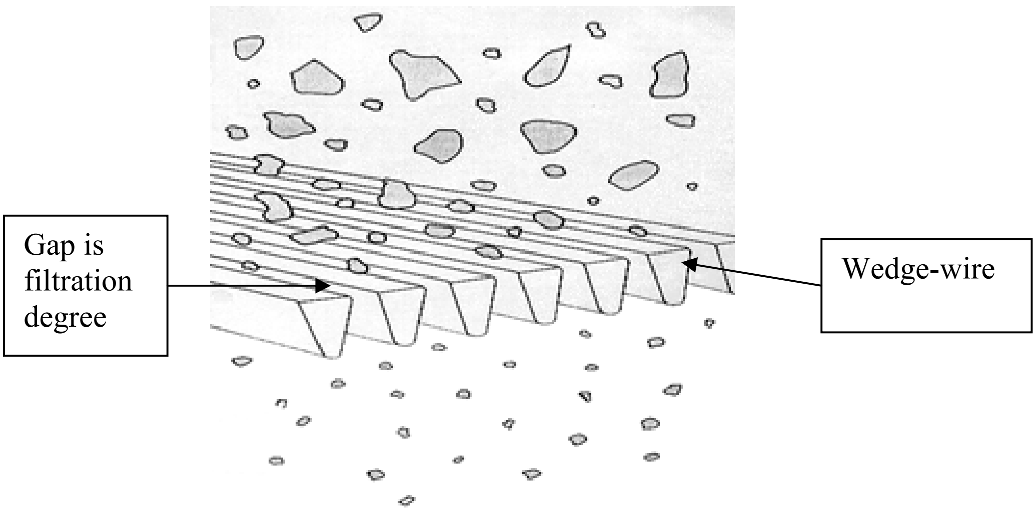

Figure 1

Notice that with a wedge-wire screen the shape of the target particles will greatly influence the efficiency of removal. Three dimensional hard particles will be removed at a much greater efficiency than flat scaly particles that could orient themselves to slip through the slots.

Weave-wire screens on the other hand, have a discrete opening. A simple two dimensional square-weave would have rectangular openings. Some manufacturers of square-weave material form a rectangular opening with the length of the rectangle 2.5 to 5 times longer than the width. Again, this can greatly affect the efficiency of the filtration process. The best square-weave is one with rectangular openings having the length and width of the rectangle equal defining a true square as shown in Figure 2.

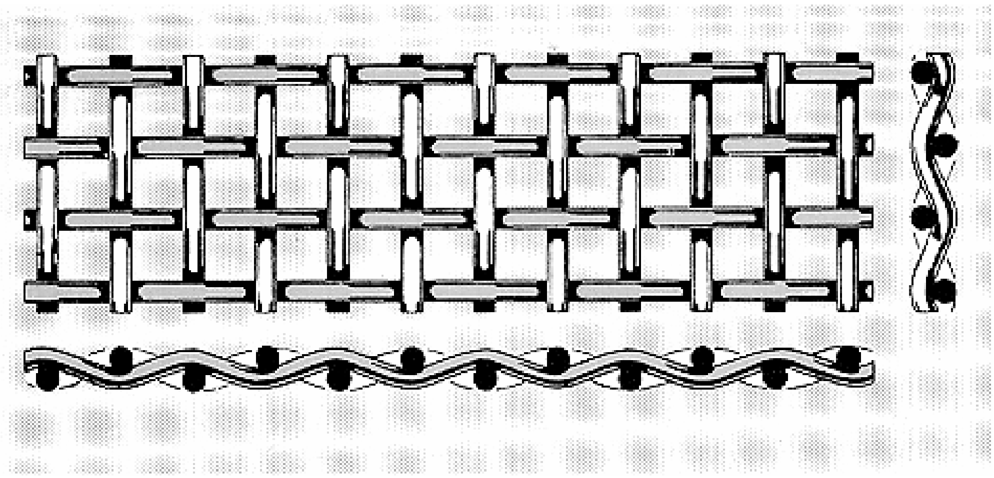

Figure 2

However, most screens today do not use a square-weave but other weaves such as Dutch Weave and Double Dutch Weave. Figure 3 shows an example of Dutch Weave.

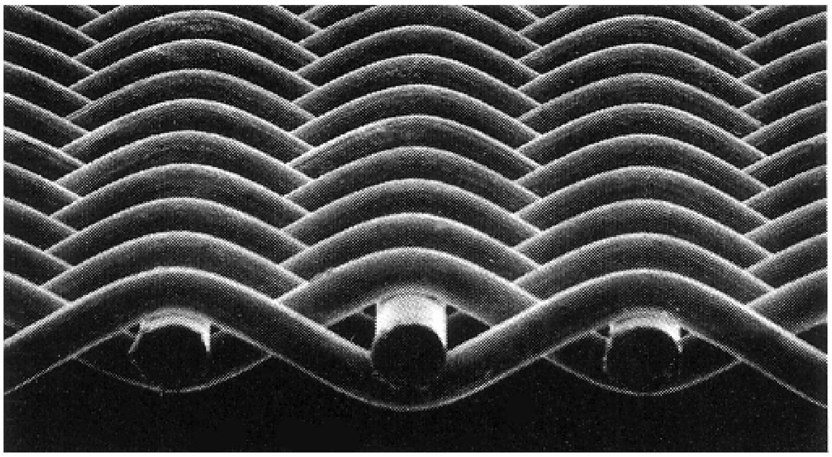

Figure 3

Note that the openings are not rectangles but a three dimensional warped triangle. The given definition of nominal and absolute filtration degrees hold in this case also. This type of weave is stronger and provides more open area (see definition below) at small filtration degrees than a simple square weave.

Another important definition needed when designing or comparing filters 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 1 where two types of screen construction are compared.

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

Table 1: Filtration Open Area

The open area of a screen filter is very important but not often considered by the lay person when specifying or comparing filtration systems. The pressure drop, or pressure loss, across a filter medium such as a two-dimensional screen is proportional to the square of the fluid's velocity. Therefore, the larger the open area of a filter screen for a given flow rate, the slower the velocity and therefore the lower the pressure drop across a clean screen. This translates to having more dirt holding capacity before the open area decreases to a degree that a preset pressure drop across the screen occurs. For a given total suspended solids concentration (see definition below), this means that the more screen open area available, the longer the time interval between cleaning cycles. Because the pressure loss across the screen element is proportional to the *square* of the velocity, doubling the open area actually increases the time interval to reach a specific preset pressure loss by *four* times.

The dirt load or *total suspended solids* (TSS) is of major concern in filtration and is best defined as the concentration of total solid particles above half a micron given in milligrams per liter (mg/L) or parts per million (ppm). This information alone offers limited help in the design of systems with filtration degrees below about 80 microns. If, along with TSS, the *particle size distribution* (PSD) is known for these finer systems, the concentration of particles in the fluid *seen* 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, or in percent volume (volume density) per size unit. Expressing PSD by volume density is much more useful in designing filtration systems than particle density. In natural waters such as rivers and lakes there can be millions of particles in the 1 – 5 micron size per milliliter making up 60% or more of the particle counts (particle density) but they may represent only 1% of the total TSS volume. Whereas, particles above 80 microns may account for only 5% of the particle count, but they may amount to 75% of the TSS by volume. Most of the time PSD analyses by particle count are meaningless for designing screen filtration systems.

Those elements that cause a filter or strainer to loose 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. Inorganic particles typically are hard three-dimensional objects that retain their shape when pressed against the screen element. Organic material tends to be soft, sticky and plastic in nature. Therefore, it has a tendency to flatten and spread over a large area when it encounters the screen surface. This results in a smaller "volume" of organic material necessary to sufficiently decrease the open area to cause a specific pressure drop across the screen than for a similar number of ridged inorganic particles.

Filtration Methods

The terms "filtration" and "straining" are often used synonymously when dealing with particle removal. 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. Screen filtration is used in residential, commercial, 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.

The cyclonic separator best exemplifies *kinetic filtration*. It is not technically a filter as defined above, but a separator. 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 has the advantage of being passive in nature with no moving parts. No clogging generally occurs with this type of separation system and a simple automated flushing valve is all that is necessary to maintain a self-cleaning system. However, cyclonic separators are limited to removing only particles with a specific gravity of 2.5 or greater and usually cannot perform efficiently below 75 microns. Therefore, they cannot remove most organic particles and are limited to performing well only on heavier inorganic solids. Because of the dynamic behavior of the cyclonic separator, each specific model performs over a limited range of flow rates. Figure 4 shows a typical cyclonic separator.

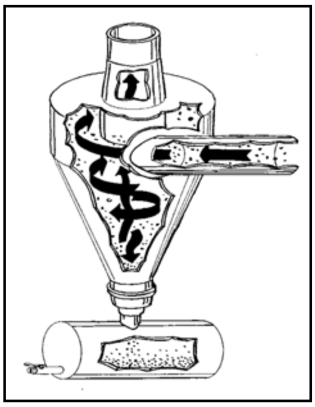

Figure 4

Filters utilizing granular media represent *contact filtration*. Suspended solids in the fluid stream are held within the media by impinging on individual media granules, adhering to the surface of media granules and becoming entrapped in dead-end channels between media granules. The long-standing sand filter shown in Figure 5 is a classic example of a contact filter. The Romans used sand bed filtration two thousand years ago and today this method is still one of the most widely used forms of filtration.

Figure 5

Surface filtration is a physical sieving process utilizing a medium such as a woven screen element to present a physical barrier to particles too large to pass through its holes or openings. Bar screens, sieves, screen filters and basket strainers adhere to this filtration mechanism. This method presents an absolute barrier to ridged particles that are larger than the openings in the filtration element. Figure 6 shows typical examples of screen filters with plastic housings and stainless steel weave-wire or perforated screen elements.

Figure 6

Filter Cleaning Methods

Filters can be cleaned by many different methods. Some simply require the filtering element to be removed, discarded and replaced with a new element. This paper will look at only those strainers with elements that are reusable. There are several common element cleaning methods in use.

The *manual cleaning* method requires the filter to be taken off-line stopping flow through the filter, the screen element removed and then cleaned by hand just as its name implies. Cleaning can be accomplished by running water, high-pressure spraying, brushing or other physical means. The filter then must be reassembled before flow can resume.

Many types of filters use a device to *mechanically clean* the screen element. These devices include brushes, wipers and scrapers. Generally this type of cleaning is best used on screens with filtration degrees of 200 microns and larger.

Direct flushing involves opening up the dirty side of the screen element to the atmosphere during the filtration process. This directly flushes debris off the screen element without reversing the direction of flow. Success of this type of cleaning is limited to only a few filter types under specific conditions.

The *back-flushing* method of cleaning can be manual or automatic and requires the filter to be taken off-line. Water is then passed through the filter in a reverse direction to remove the solids from the media or element and expel them from the filter body. Sand media filters are cleaned by this method and some manufacturers of screen filters attempt to use this method of cleaning. However, a basic principle of physics is often overlooked when using this method for screen filters. Once the cleaned open area of the screen (the sum of open holes) reaches the same square inches as the inlet and outlet flanges, the velocities are equal throughout the filter system and no additional screen cleaning can occur. Since most filters have screen open areas equal to 5 to 10 times the cross-sectional area of the inlet and outlet flanges, the differential pressure across the screen will measure zero after a short back-flush cycle but only a small portion of the screen is really clean. This results in very short intervals between cleaning cycles.

Forced back-flushing or "suction scanning" is the process of developing a suction force by reversing the flow through a small portion of the screen element, usually less than 2 square inches of effective filtration area. The differential pressure between the positive working pressure of the system and atmospheric pressure creates very high velocities traveling backward through this portion of the screen area thereby pulling the debris layer, called a filter cake, off the screen. This small area is then moved across the screen surface to progressively clean the entire screen. This cleaning method can be manual or automated. Figure 7 gives details on one such small 2” plastic manual system. When the flush valve on the bottom of the filter is opened it connects the inside of a hollow tube, called a suction scanner, located down the middle of the cylindrical screen element to atmospheric pressure or zero gauge pressure. Coming out radially from the suction scanner are nozzles with small openings within a few millimeters of the screen surface. Because the pressure inside the filter housing is 35-150 psi, water at very high velocities moves backwards through the screen in the vicinity of the nozzle openings pulling the filter cake (debris) off the screen surface, sucking it into the suction scanner and blowing it out the bottom flush valve. The suction scanner is attached to a hand crank at the top of the filter which has a threaded shaft and fixed nut. As the crank is rotated the suction scanner not only rotates but slowly moves linearly causing each nozzle to have a spiral movement. Within a few seconds every square inch of the screen surface is sucked clean of debris. The flush valve is then closed until the next cleaning cycle is required. This procedure can be manual requiring about 30 seconds of labor or completely automated with PLC controls. Filter sizes can range from 2” to 20” inlet and outlet flanges with flow rates up to 17,000 gpm per automatic filter.

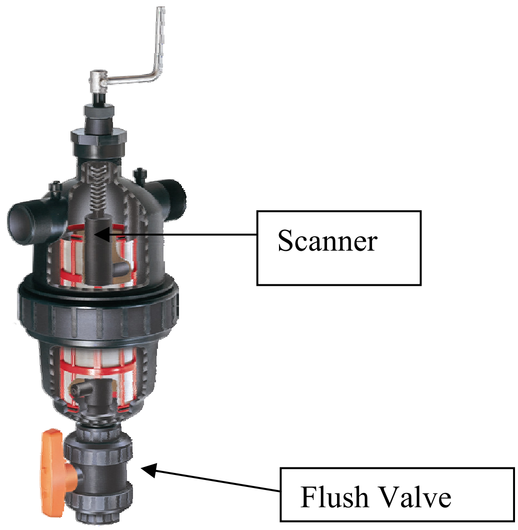

Figure 7

Applications
Weave-wire 316L stainless steel screens are strong and long lasting, capable of withstanding a pressure differential across the screen of up to 250 psi with no distortion. Filtration degrees are available from 3500 microns down to 10 microns. Macro-particles typically removed by screen filters include sand, silt, pollen, insects, fibers, pipe scale,

rust flakes, phytoplankton (algae), zooplankton, metal fines, metal hydroxides, vegetable matter, weld balls, sealer, plastic chips and all life forms of zebra mussels including their eggs, to mention a few. They are found in commercial and residential applications as well as industries such as automotive, foundry, mining, irrigation, food processing, pulp & paper, plastics, municipal water supply, wastewater treatment and penguin ponds at the zoo.

Municipalities are finding screen filters to be the economical choice for pre-treatment of surface water sources. These filters remove sand and silt resulting from snow melt and spring rains. Screen filters easily remove heavy organic material caused by late summer algal 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 and stormwater treatment facilities that cannot discharge effluent year-round are finding that automatic self-cleaning screen filters allow them to stay within regulatory limits. Effluent 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 detention ponds often cannot meet the daily solids load limit imposed by regulatory permits. A small pump and automatic screen filter can solve this problem very economically.

Screen filters coupled with a 10 to 50 micron stainless steel weave-wire 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 screen filter and the membrane system to polish the influent. Either way, screen filters can provide a fully automatic self-cleaning system to remove all or nearly all of the suspended solids that would cause havoc with typical membrane treatment systems.

Due to its low maintenance and attention requirements, automatic self-cleaning screen filters lend themselves to industrial and commercial cooling tower systems. Installed either as a side-stream or full flow system, these filters will maintain clean cooling fluid to prevent the clogging of spray nozzles or the coating of heat exchange surfaces.

Commercial businesses find screen filters to be a proven economical means of removing sand, rust flakes and pipe scale from their municipal water source. Bakeries, restaurants, coffee shops and hotels enjoy the freedom from clogged nozzles, ice machines, faucet aerators and heat exchangers without the costly and time consuming job of replacing cartridges in their filtration system.

Home owners can protect their faucet aerators, ice makers, water softeners, lawn and landscape irrigation systems, dishwashers and washing machines from sand, rust flakes, pipe scale and other debris whether on a well or municipal water line. Those with lake homes, cottages, campers and summer dwellings are happy to find that screen filters can remove inorganic sand and rust flakes as well as organic algae and “critters” from ponds, rivers, lakes and cisterns efficiently and economically. Even surface and sub-surface irrigation waste disposal systems are easily protected with screen filtration systems.

Summary

Manual and fully automatic self-cleaning screen filters provide an economical means of removing suspended solids down to 10 microns from water streams. Filters equipped with the efficient suction scanning principle allow 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 clean water downstream of the filters 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, screen filters lend themselves to many uses in municipal, industrial, commercial and residential applications. Screen filters eliminate the cost and labor associated with replacement cartridges and can be automated for added convenience.