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### **Removing Solids with Automatic Self-Cleaning Filters**

#### 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. This manuscript will concentrate on only automatic self-cleaning 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 cleaning. There are a number of automatic methods in practice to eliminate the need for labor when cleaning the permanent screens in this class of filter. However, some work better than others. This paper will discuss one type of automatic self-cleaning screen filter having a proven record with tens-of-thousands of successful installations around the world.

#### 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 approximately 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 the screen 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 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.

### Screens

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.

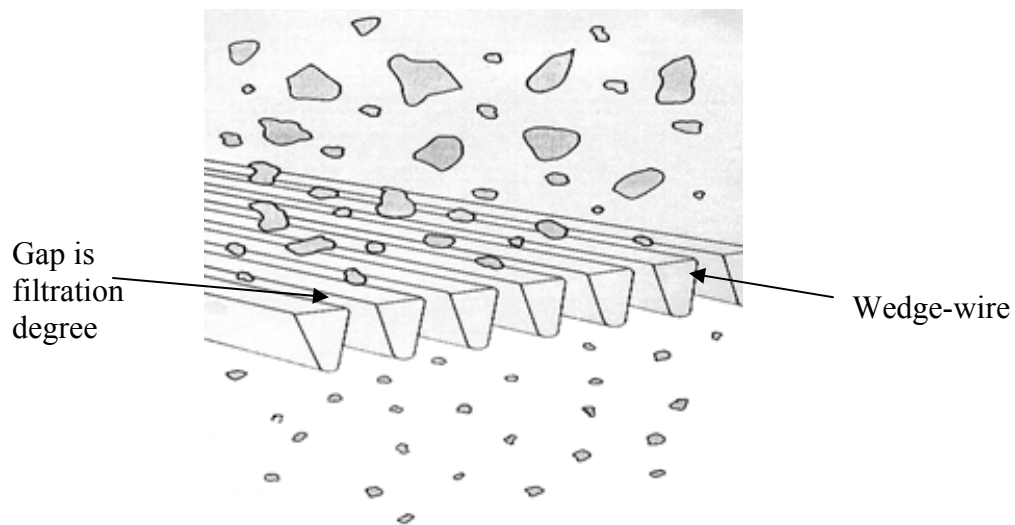


Figure 1: Wedge-wire

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.

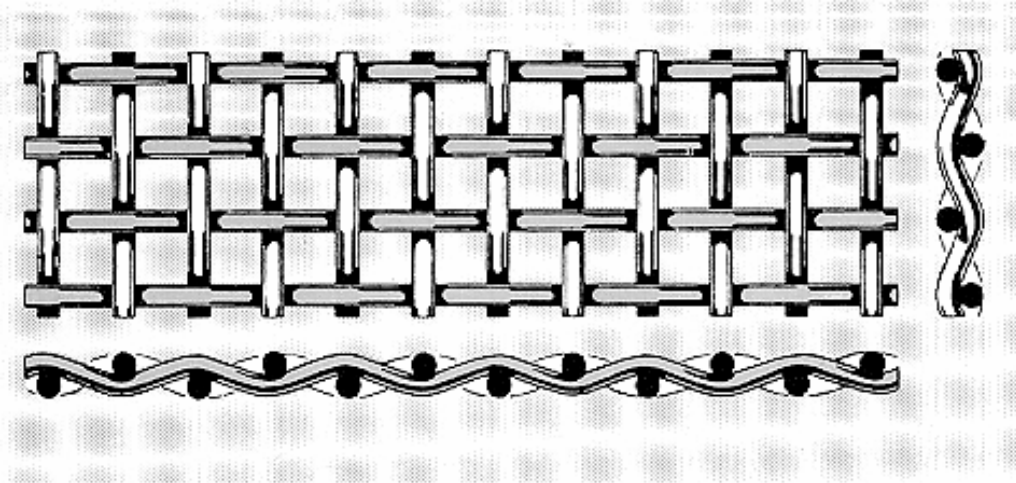


Figure 2: Square Weave

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.

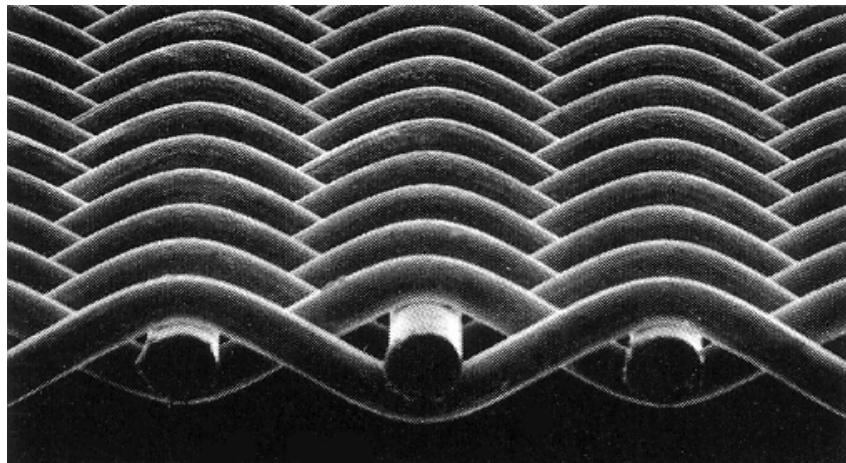


Figure 3: Dutch Weave

Note that the openings are not rectangles but can best be described as three dimensional warped triangles. This type of weave is stronger at small filtration degrees than a simple square weave. 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.

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 DEGREE	FILTRATION OPEN AREA	
	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 directly 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, 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 screen found in the filter to be described below has a four-layer 316L stainless steel construction as shown in Figure 4. This patented screen is unique to the filtration industry. The bottom layer against the dirty water flow is a coarse grid to protect the actual filtration layer from damage by hard, sharp foreign objects that may pass through the supply pump such as rocks or pieces of metal or glass. Damage to the filtering layer inside a pressurized filter vessel would go unnoticed by the operator until a failure occurred downstream due to inadequate protection from suspended solids. This first layer minimizes the possibility of this happening. The second layer is the true filtering medium. It is this layer that prevents particles larger than the filtration degree from passing downstream. The size of openings in the layer can vary from 3500 microns down to 10 microns depending upon the filtration degree selected for the application. The third layer is identical to the first and helps hold the filtering layer in place. Layers one and three do not tightly sandwich layer two but allow the filtering layer, layer two, to float between them providing 100% utilization of the open area of the filtering layer. Layer four is a series of wedge-wires welded together in a 7/16" grid to add strength and structural rigidity to the entire screen assembly.

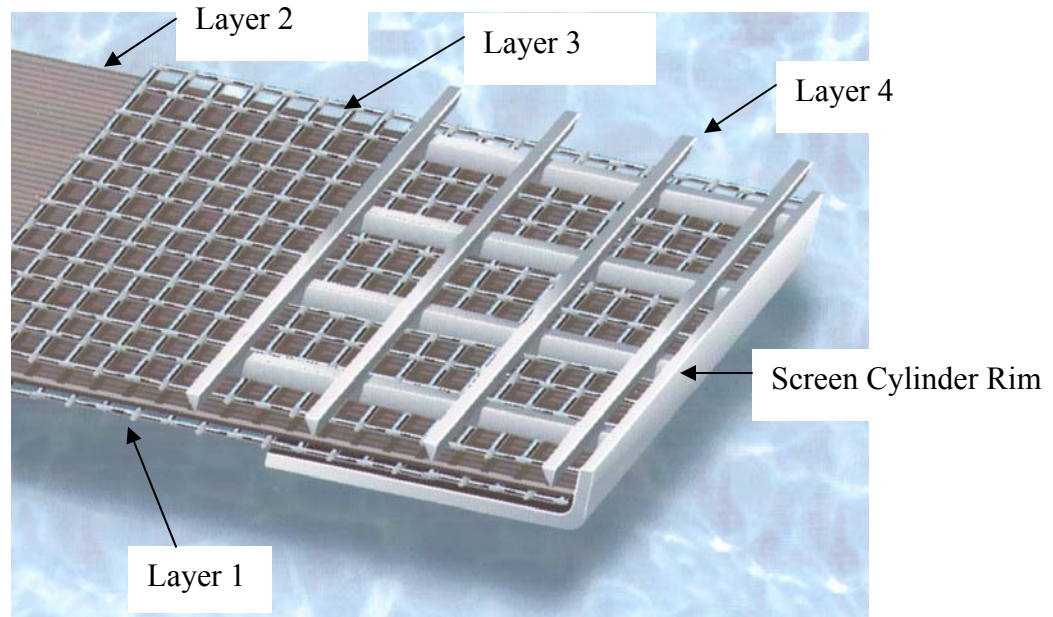


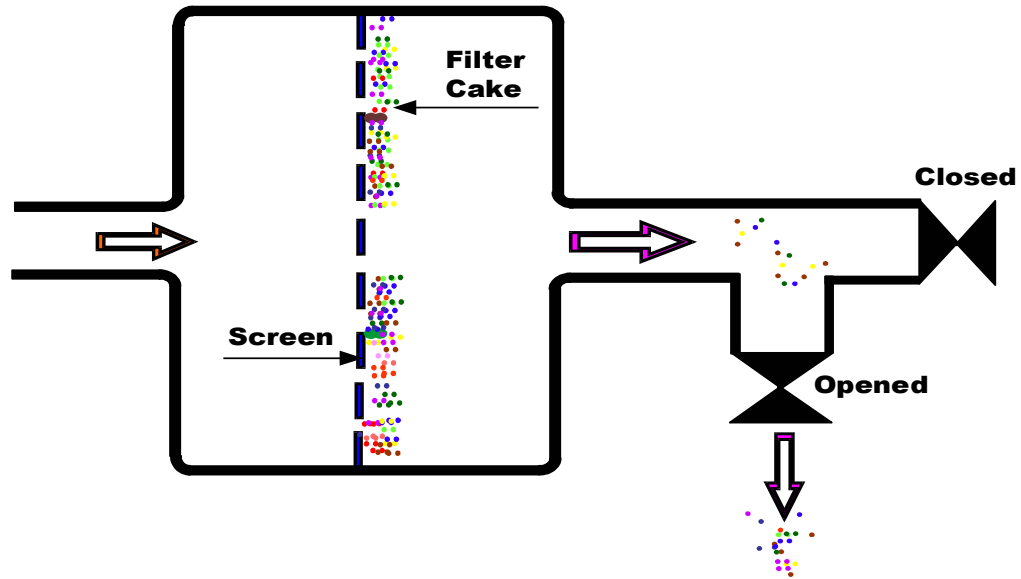
Figure 4: Patented Four-layer Screen

#### Automatic Cleaning Methods

*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 very limited and then only under specific conditions.

The *back-flushing* method of cleaning requires the filter to be taken off-line. Water is then passed through the filter in a reverse direction from normal flow to remove the solids from the media or element and expel them from the filter body. See Figure 5. 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 area (e.g. square inches) as the inlet and outlet flanges, the velocities are equal throughout the filter system. Since this also implies that energies are equal, there is no energy differential across the screen, therefore; no additional screen cleaning can occur. Since most weave-wire screens have 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 since only a portion of the screen is available to really catch more debris.

*Focused back-flushing* or "suction scanning" is the process of developing a suction force by reversing the flow through a small portion, about 1 square inch, of the screen element as shown in Figure 6. The differential pressure between the positive working pressure of the system, 35-150 psi) and atmospheric pressure, zero gauge pressure, creates a very



← Normal Direction of Flow during Filtration

Figure 5: Simple Back-flushing

high velocity water stream traveling backward through this small portion of the screen area, thereby; pulling the debris layer, called a filter cake, off the screen. This small area is then slowly moved across the screen surface to progressively clean the entire screen.

#### Fully Automatic Self-cleaning Screen Filter

The following is a brief description of how a fully automatic self-cleaning suction scanning filter operates. Dirty water flows into the filter through the inlet flange at the bottom of the filter body as shown in Figure 7. Water then proceeds through the cylindrical 316L screen element from the inside out causing particulates larger than the filtration degree (pore size) of the screen to accumulate on its inside surface forming a filter cake. Effluent leaves the filter body through the flanged opening on the side of the filter body. A pressure differential switch (PDS) continuously senses the pressure differential across the filter screen. The PDS signals the programmable logic control (PLC) to initiate the cleaning cycle of the filter screen when the filter cake causes a pressure differential of 7 psi. During the cleaning cycle, there is no interruption of flow downstream of the filter. Pressure loss through the entire filter containing a clean screen is less than 2 psi at maximum design flow rate and is usually less than 1 psi. This results in a total pressure drop across the filter remaining at less than 2 psi most of the time but building up to a maximum of 9 psi just before a cleaning cycle is initiated.

The filter screen cleaning mechanism is a suction scanner constructed of a 316 stainless steel assembly that rotates while also moving linearly. The suction scanner consists of a central tube with six tubular nozzles equally spaced along the length of the central tube positioned perpendicular to the longitudinal axis of the central tube. A 3" flush valve

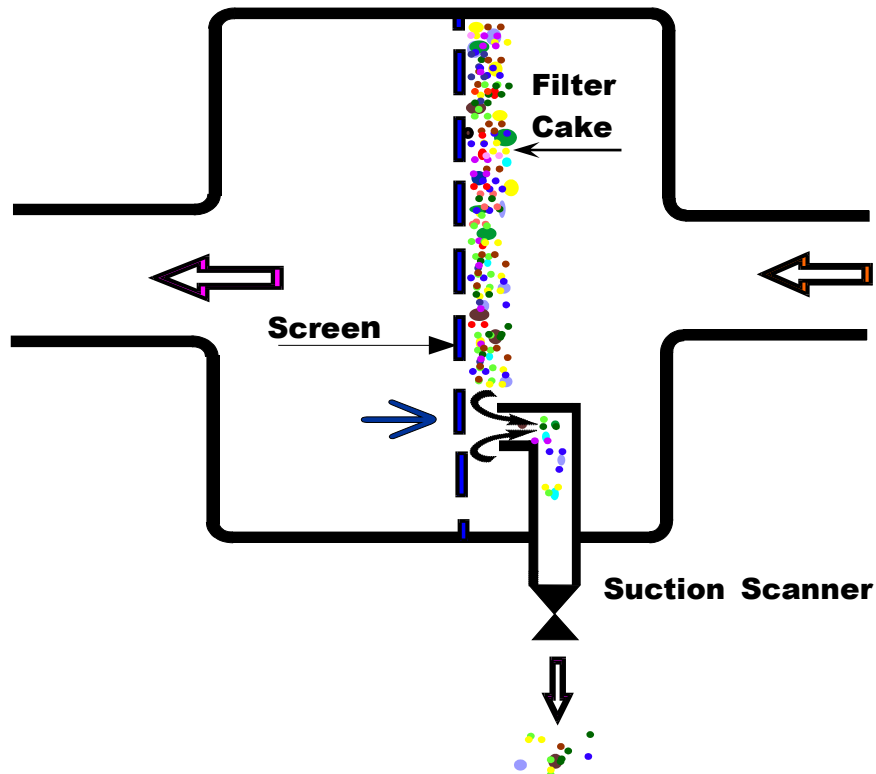


Figure 6: Focused Back-flushing

connects the internal cavity of the suction scanner to atmospheric pressure outside the filter body. By opening the flush valve, 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 very high velocity 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 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 less than 40 seconds, during which time the nozzles remove the filter cake from every square inch of the filter screen.



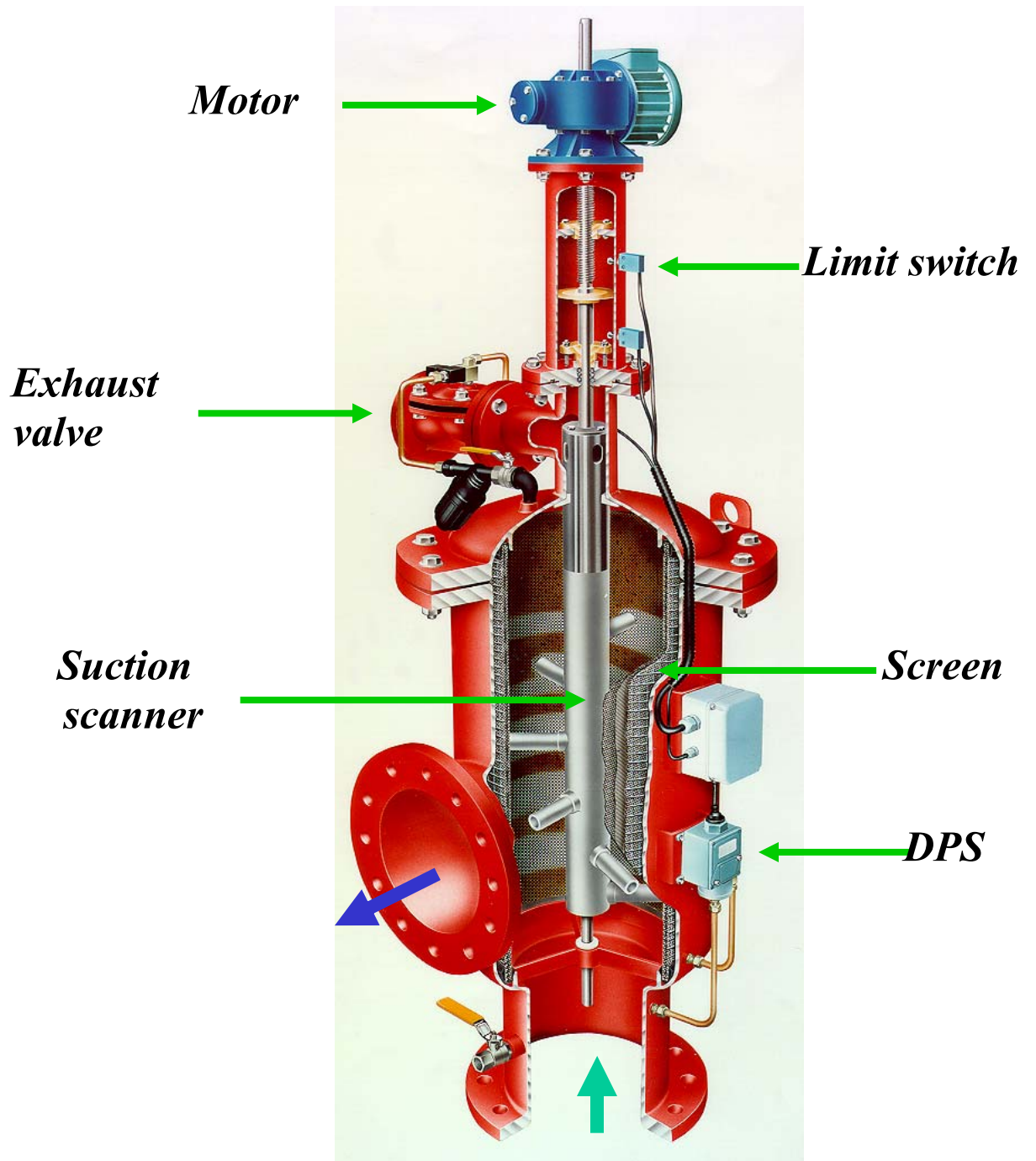


Figure 7: Automatic Self-cleaning Filter

A 1/2-hp electric gear-head motor drives the suction scanner. The connection between the motor and suction scanner assembly consists of a threaded shaft traveling inside a fixed threaded bearing. This arrangement gives the suction scanner its rotational and linear movements; thereby, giving the suction scanner nozzles their slow spiral motion along the inside of the filter screen. The suction scanner has a rotational speed of about



24-rpm and a linear speed of around 12-ipm at 440-vac and 60-Hz. Two normally closed limit switches stop the electric motor and provide feedback to the PLC to control its direction of rotation. The filter never goes off-line and filtered water is provided downstream even during the short cleaning cycle.

### Applications

This type of fully automatic self-cleaning screen filter has been used for decades in applications wherever suspended solids need to be removed from a pressurized water stream. They are used to remove sand, silt and algae from raw water taken from lakes, ponds, rivers and canals. Such filters provide pretreatment before membrane filtration systems for potable water supply. Other installations include pretreatment for reverse osmosis and other desalination systems. Many municipal and industrial wastewater treatment plants use these filters to prepare secondary effluent for reuse in cooling, irrigation and aquifer recharge systems. Applications in steel mills filtering grimy, oily cooling and descaling water are common as are those in the automotive and plastics industries. Cement plants and mining operations use this type of filter for removing solids from tailings. They are found on deep-sea oil platforms for filtering flood water and on ships before portable desalination systems.

### Summary

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, automatic self-cleaning screen filters lend themselves to uses in industrial, municipal and commercial applications. Fully automatic self-cleaning screen filters eliminate the cost and labor associated with replacement cartridges and can be integrated into SCADA or other monitoring systems.