

SCREEN FILTRATION TECHNOLOGY AS APPLIED TO PRETREATMENT OF REVERSE OSMOSIS AND ULTRA-FILTRATION SYSTEMS

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Summary: New developments in the manufacturing technology of stainless steel weavewire screens enable mechanical style self-cleaning filters to be utilized as the primary pretreatment device for R-O and U-F systems. These systems are more cost effective and feature lower O&M requirements, than multimedia filters.

INTRODUCTION

Recent advancements in the manufacturing technology of woven stainless steel screens has created new applications for mechanical filtration systems. One such application is the pretreatment of water supplied to Reverse Osmosis and Ultra-Filtration systems. Standard practice for pretreatment is a multimedia depth filtration system followed by disposable cartridge filters ahead of the RO/U-F system.

The introduction of self-cleaning mechanical filters, which are effective removing a significant portion of the particles as fine as 1 micron in size, allow plant designers an alternative to multimedia systems. The advantages of mechanical filters are simplicity of operation, small footprints, less complexity in piping and valving, as well as higher efficiency resulting in reduction of the backwash water by 60-80%.

This paper describes three sites where a mechanical filter is used as the pretreatment to an R-O system in an electric utility. Two of the cases are permanent installations and the third uses data gathered during a pilot study on two separate water sources. Filtration data is presented for well water, river water, canal water and reservoir water. The effectiveness of the mechanical filter on each water source is compared.

FILTER DESCRIPTION

Mechanical filtration has been in use for over 20 years with screens having filtration capabilities of 40 micron and above. Developments in manufacturing technology of woven stainless steel screen over the past 10 years has enabled mechanical filters to remove particles in the 15 micron range. The screen used in the test, introduced in 1996, have proven effective in removal of particles as fine as 1 micron. The filter which was used in the Case Studies is shown in Figure 1.

There are a variety of mechanical filtration systems available on the market; each with its own unique screen construction and self-cleaning design. The systems and filtration performance described in this paper are based upon the patented designs of Amiad Filtration Systems.

Mechanical Filters incorporate an in-line filter body, which houses a screen to capture the suspended solids in the water stream. The system measures a differential pressure across the screen surface to determine when to initiate the cleaning cycle. As particulate builds, the DP will rise to 7 psi, which will start the cleaning cycle.

FILTER CONSTRUCTION - The 10 micron filter is available in three body styles, supplied with flange connections from 4 inch to 8 inch diameter, depending upon the design flow. Filters are rated at flows from 70-800 gpm per unit.

Body - The standard filter body is rated at 150 psi and constructed of carbon steel material. The body received 5 coats of epoxy on the interior and exterior surfaces.

Screen - The screen construction is the significant development which allows mechanical filters to be used as R-O prefilters. Utilizing European technology, the screen is manufactured entirely of 316L Stainless Steel. In a joint R&D effort, the filter OEM and the screen manufacturer brought the screen rated at 10 micron to market in mid-1996.

This "working" screen is woven in a 600 mesh square weave pattern. The square weave is a critical factor in maintaining the integrity of filtration. The tight, square weave keeps the screen ridged and wire spacing intact so the screen continues to provide the same particle removal efficiency over its service life. Screens woven in 1:2.5 or 1:5 rectangular patterns can distort or separate over time and allow smaller particles to pass.

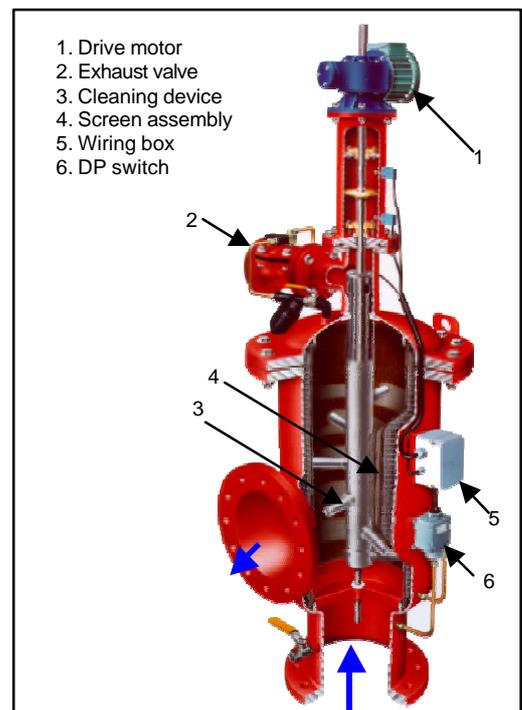


FIGURE 1. Cut View of a Mechanical Filter

Protection of the "working" screen while maintaining the ability to provide automatic self cleaning is critical in evaluating the filter design. The filter in this study resolved this by sandwiching the working screen between two heavier mesh screens and installing a retaining ring on either end to keep the components together. This patented assembly is then welded together to become a single, integral unit. Screen thickness of the assembly is 3/16", allowing the suction device close proximity to the filtered material, enabling it to remove debris from the clean effectively.

FILTER OPERATION

The filter has flanged connections and is arranged so that the water flows from the inside of the screen out: collecting suspended material on the inside screen surface. A typical installation will have a clean condition pressure drop of 1-2 psi. As the silt builds on the screen and the DP rises to 7 psi, the cleaning cycle is initiated by a differential pressure switch.

The self-cleaning mechanism consists of a hollow shaft down the centerline of the filter body. This shaft has nozzles which extend to approximately 1/8" from the screen surface. The shaft is sealed on one end and open to an exhaust chamber at the top of the filter. When the exhaust valve is open, the differential pressure between the supply pressure and the atmospheric pressure at the outlet of the exhaust chamber create a powerful vacuum effect at the end of each nozzle. This sucks the material from the screen surface, through the shaft and out the exhaust valve.

The start of the cleaning cycle causes the exhaust valve to open to atmosphere and the electric motor to start. The motor simultaneously rotates the shaft at 17 rpm and moves the shaft axially so the nozzles cover the entire inner screen surface during each cleaning cycle. The duration of the cleaning cycle is 17-45 seconds, depending upon the style of the filter.

EVALUATION OF FILTER EFFICIENCY

The primary function of the filtration device is to separate out solids or particles from a water stream. The most common indices used for determining water quality are Silt Density Index (SDI) and Turbidity.

SDI, the standard by which ROO/UF inlet water quality is measured, is defined as the rate of pluggage of a 0.45 micron filter over a fixed time period and at a constant gage pressure.

Turbidity, expressed in NTU, measures clarity by determining the amount of light allowed to pass through a water sample.

Each of these values are valuable as a water quality measurement. However, they also have their limitations when used as tool to evaluate the efficiency of a filter. Since both are indirect indicators, the measurements provide no details regarding the number, size and distribution of particles in the water.

Evaluation of the filter efficiency in this study uses a scattered light laser particle counter manufactured by Spectrex, to establish the quantities and distribution of particles. The water sample to be checked is dropped into a beaker of particle free distilled water and ultrasonically cleaned for up to 30 seconds. The beaker is then placed in the "in-situ" particle counter where a laser beam is passed through it to scan the volume for particles. Two different lenses determine the size and number of particles in the 1-167 micron range and the 16-100 micron range. The size is measured and displayed on the computer screen and printout. Precision of this optical method appears to be very good. Testing of replicate samples show that the variation of particle counts is less than 5%.

The writer was unable to find any published data which would correlate SDI and particle counts. While the data developed in these tests and at other sites shows no direct relationship; it must be noted that the amount of this data is limited at present.

SYSTEM DESIGN CRITERIA

In order to design the system, the data required includes:

- Water source
- Detailed PSD analysis/TSS loading
- Minimum/Maximum Flow rates
- System Pressure
- Nature of solids

The capacity of a filter is directly related to the screen surface area. The TSS loading into a 10 micron screen is typically limited to 18 ppm. With water which has a heavier TSS loading, two filters may be run in series with the first filter using a 25 micron screen and the second with the 10 micron screen. For larger systems, filters may be manifolded to achieve any rated flow.

CASE STUDIES

CASE #1 - WELL WATER SOURCE.

The first case study is from a coal fired utility plant near Las Vegas, NV. The plant purchases water from a local water district which draws from a deep well. Water is supplied to a Reverse Osmosis system.

Original pretreatment for the system was a sand media filter. The plant experienced problems with the media filter in several areas: first was media carryover, second was the backwash water rates. Downstream of the sand filter where 1 micron cartridge filters which are part of the RO skid. The system is designed for 250 gpm system flow. The plant elected to eliminate the sand filter upstream of the cartridge filters to reduce the carryover problems, essentially using the raw well water for the RO Feed. This resulted in changing of the 1 micron cartridge filters every two weeks, as costly maintenance expense.

The plant engineers reviewed available filtration options and determined that screen filtration was the least cost, most effective option for pretreating the RO. After the installation of a 6" filter, water samples were analyzed using the laser particle counter. A graphical representation is shown in Figure 2.

Results showed the screen; rated by the filter manufacturer at 10 micron, removed 99% of the particles over 5 micron and 86% of the 1 micron particles. The Total Suspended Solids (TSS) of the raw well water was 10.46 ppm. The filter effluent TSS was determined to be 2.5 ppm.

This system has been in operation for 2 years with no reported operating or maintenance issues.

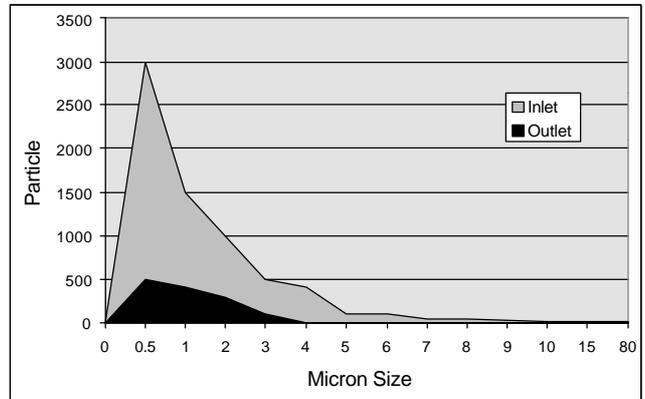


FIGURE 2. Well Water, Particle Removal

CASE #2 - RESERVOIR WATER SOURCE.

The second case study is from an installation at a coal fired utility plant in eastern Wyoming. This plant draws water from a river fed reservoir, into a holding pond on the plant site. Testing was performed in June and a fairly low level of suspended solids were detected in the supply water. The original plant pretreatment system included a bank of carbon media filters followed by 10 micron bag filters and 5 micron cartridge filters. The water is then fed into three RO machines.

The plant was experiencing problems with the cartridge filters plugging. The pluggage was due to TSS material which passed through the media filters. In addition, there were intermittent problems with the carbon media carrying over into the process stream. A mechanical screen filter was installed in June, 1998. The unit was installed in parallel with the 10 micron bag filters, which the plant engineers elected to keep as a backup system. The system uses a single filter with 8 inch flanges to treat 800 gpm.

Particle size distribution analysis of the filter inlet and effluent stream show the mechanical filter is removing over 90% of the suspended material, reducing the TSS from 0.49 ppm to 0.04 ppm. Comparison of the well water results to the reservoir water particle removal in Figure 3, shows the filter removes a higher percentage of 1-4 micron particles from the well than the reservoir water.

The well water effluent had no particles over 5 micron compared to the reservoir water effluent where particles were detected in all bins 10 micron and below. The particle counts in the 5-10 micron bin were low, all less than 40 particle counts, and accounted for 0.03 ppm mass.

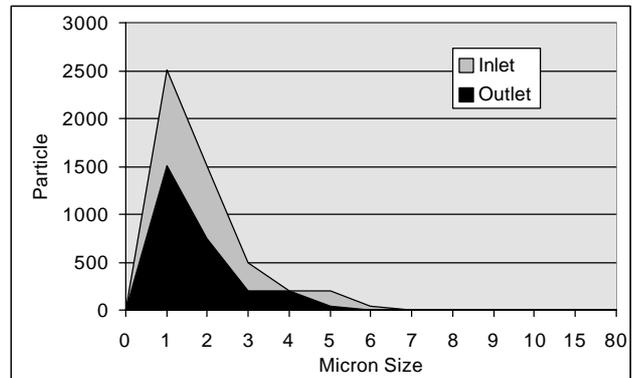


FIGURE 3: Reservoir Water, Particle Removal

A primary factor in justification for the mechanical filter was the insurance that if a major upset occurred in the carbon filters resulting in carbon carryover, the mechanical filter's stainless steel screen offered 100% protection against any media reaching the RO membrane. With bags and cartridges, it is possible for media to pass through torn bags, or cartridges which may not be seated properly.

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CASE #3 RIVER/CANAL WATER SOURCE

The third case study is based upon a pilot test performed at a utility plant in California. The plant can operate on two different water sources. The first being the Contra Costa canal, which is fed from the San Joaquin River; the second source is Sacramento River water. For the pilot test, the water was treated directly by a four inch filter with a 10 micron screen. Testing was performed at reduced flows to prevent overloading the screens ability to self clean. Data is presented from both water sources which provided very interesting results.

The canal water source was reduced from a TSS of 1.51 ppm to 0.08 ppm at the filter outlet, a reduction of 96% of the solids. AS Figure 4 shows, the screen filtered particles in the 105 micron range very effectively. Limited numbers of suspended solids in the 5-20 micron range passed through the screen; no particles over 10 micron were observed on the downstream side of the filter.

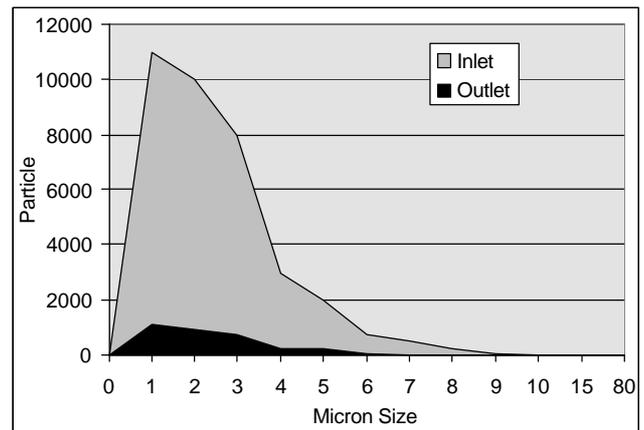


FIGURE 4: Canal Water, Particle Removal

The Sacramento River water at this site produced very different results from any of the other testing performed. Suspended solids loading into the filter was reduced from 35.12 ppm to 28.33 ppm, a 20% reduction of the mass. As the graph in Figure 5 will show, the particle counts actually increased in the effluent water in select micron bins. In addition, this is the only testing where a substantial amount of mass over 10 micron in size (11.7 ppm) is detected in the filter effluent. This phenomenon is discussed in detail in the Analysis section of the paper.

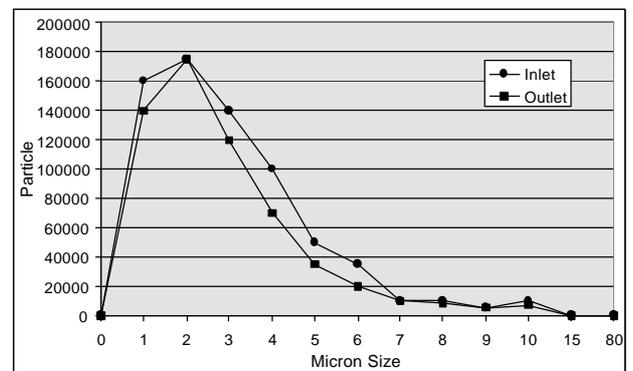


FIGURE 5: Sacramento River, Particle Removal

ANALYSIS AND DISCUSSION

BEHAVIOR OF SUSPENDED SOLIDS - The effectiveness of mechanical filtration is directly affected by the nature of the particulate being filtered. The graphs shown in Figures 2 and 5, showing particulate removal of well water and Sacramento River water, represent the opposite ends of the spectrum.

When the suspended particles are hard in nature, is the case with well water, the results are very predicable and will reduce TSS levels to parts per billion levels. Removal efficiencies will consistently match the data in Case Study #1.

The mechanical filter is least effective when the suspended particulate is very soft in nature. The Sacramento River water approaches a worst case scenario in that the particles are not only very soft, and break up upon impact on the screen surface; but are also highly charged and re-agglomerate downstream of the filter. A second characteristic of the softer particles is that they can "extrude" through the screen surface. Rather than being trapped on the screen and increasing the filtration efficiency by bridging the pore opening so the screen, the soft particles are pliable and pass through the screen.

Table 1 provides data showing the amount of mass removed from each water source in the study. Experience shows it is more common to see the filter remove 90-96% of suspended solids in a surface water stream than the 19% removal on the Sacramento River.

TABLE 1. TSS mass removal for different water sources.

	Well	Reservoir	Canal	River
Inlet Mass(ppm)	10.48	0.49	2.51	35.12
Outlet Mass(ppm)	0.00	0.04	0.08	28.33
% Removal	100%	92%	97%	19%

Comparison of the reservoir and canal water shows a portion of the solids in the 6-10 micron range will pass through the screen by extrusion. Figures 3 and 4 show the canal water allows more particulate over 8 micron in size to pass through the screen. AS both sources are fed from rivers, then allowed to settle, it can be surmised that the canal water particles are softer in nature than the reservoir water.

EVALUATION OF PARTICULATE

When designing a prefiltration system it is imperative that a detailed Particle Size Distribution (PSD) analysis be performed. Well water is a fairly consistent water quality with hard suspended particles and one PSD is generally adequate.

Surface water supplies, depending upon the type of water, regional location and level of suspended solids often requires a second laboratory evaluation. Microscopic evaluation of the particles is performed while they are run through a filtration apparatus under a vacuum of 25" Hg. The particles are viewed to determine if there is any deformation under the vacuum. Experience with predictability of this is limited, but to date this has proven to be reasonable simulation of how these particles will react while on the screen surface of a mechanical filter.

ADVANTAGES OFFERED BY MECHANICAL FILTERS

Mechanical filters offer many advantages over traditional multimedia systems:

- ◆ Capital cost of the equipment is 30-50% lower.
- ◆ Water required for backwash is <1% on mechanical filters compared to 5-7% for mm.
- ◆ Energy costs are lower, with a 2-7 psi operating range across a screen filter.
- ◆ Flocculation chemicals are not required.
- ◆ Mechanical systems require a smaller footprint and less complicated valving arrangements, especially important in many retrofit applications.
- ◆ Mechanical screens have a service life of 8 years.
- ◆ Screens protect R-O membranes, ensuring suspended solids do not pass down stream.

CONCLUSION

The use of mechanical filters for R-O and UF prefiltration is a viable alternative which merits consideration in the design or retrofit of a water treatment plant. An inexpensive water analysis can be performed to determine the suitability of mechanical filtration on any water supply. The advantages outlined for mechanical filtration systems over traditional pretreatment systems are justified when, evaluated on a capital investment or an operating and maintenance basis.

ACKNOWLEDGMENTS

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Steve Springer, Amiad Filtration Systems.

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