

Technical Evaluation of Side Stream Filtration for Cooling Towers

Background

Cooling towers are an integral component of many refrigeration systems, providing comfort or process cooling across a broad range of applications. Cooling towers represent the point in a cooling system where heat is dissipated to the atmosphere through evaporation. Cooling towers are commonly used in industrial applications and in large commercial buildings to release waste heat extracted from a process or building system through evaporation of water.

Cooling tower systems operation is most efficient when the heat transfer surfaces are clean. However, these are dynamic systems due in part to their operating environment and because of the nature of their application. Cooling towers operate outside and therefore are open to the elements, making them susceptible to dirt and debris carried by the wind. Further, they often experience wide load variations and their operation can be significantly influenced by the quality of the water used for makeup in the system.

The combination of process and environmental factors can contribute to four primary treatment concerns encountered in most open-recirculating cooling systems: corrosion, scaling, fouling, and micro-biological activity. As shown in Figure 1, these treatment concerns are inter-related such that reducing one can have an impact on the severity of the other three.

- **Corrosion:** Corrosion is an electro-chemical or chemical process that may lead to the premature failure of system metallurgy.



Cooling Towers (photo from Pacific Northwest National Laboratory)

- **Scaling:** Scaling is the precipitation of dissolved mineral components that have become saturated in solution, which can lower efficiency of the system.
- **Fouling:** Fouling occurs when suspended particles or biologic growth forms an insulating film on heat transfer surfaces. Common foulants include organic matter, process oils, and silt, which can also lower system performance.
- **Microbiological Activity:** Microbiological activity refers to microorganisms that live and grow in the cooling system that can contribute to fouling and corrosion.

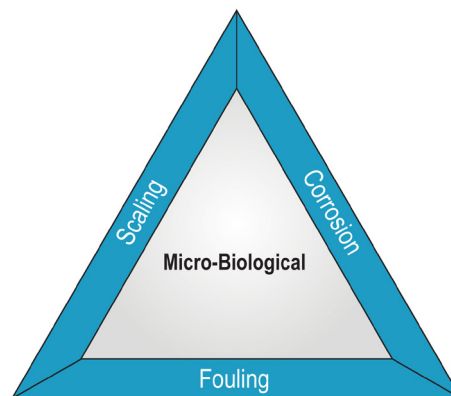


Figure 1. Cooling Tower Primary Treatment Concerns

Side stream filtration systems reduce suspended solids and debris in the system cooling water, which leads to less fouling in the system. Decreasing suspended

solids can also help reduce biological growth in the system because suspended solids are a good source of food for microbiological organisms. Decreasing biological growth in turn helps to reduce microbiologically influenced corrosion. In addition, scaling can be reduced from side stream filtration by limiting fouling and corrosion byproducts which can also contribute to scale formation on the heat exchange surfaces. Effectively managing these conditions can optimize system performance, often resulting in moderate to significant energy and water savings.

Full flow and side stream filtration are the two most common methods used to filter the water that is pumped into the circulation systems. Full flow filtration uses a filter installed after the cooling tower on the discharge side of the pump. This filter continuously filters all of the recirculating system water in the system. Inherently, the filter must be sized to handle the system's design recirculation rate. Side stream filtration, on the other hand, continuously filters a percentage of the flow instead of the entire flow. It can be a cost-effective alternative to full flow filtration that can easily improve the water quality to reduce water consumption and ensure efficiency of the cooling systems. And unlike full flow filtration, side stream filtration systems can be cleaned while the cooling systems are online, avoiding the need for planned downtime (BAC 2012).

Technology Characterization

Side stream filtration systems continuously filter a portion of cooling water to remove debris and particles. Filtered water is then pumped back into the main condenser line through a nozzle or returned to the cooling tower basin (called the sump). Figure 2 below shows a simplified cooling tower schematic, including the two example locations where side stream filtration can typically be installed. These systems remove suspended solids, organics, and silt particles for a portion of the water system on a continuous basis, reducing the likelihood of fouling and biological growth, which helps to control other issues in the system such as scaling and corrosion. This improves system efficiency and often reduces the amount of water rejected from the system. There are a variety of filter types, which generally fall into four basic categories: screen filters, centrifugal filters, sand filters, and multi-media filters (WPCP 2012).

Side stream filtration requires a minimum supply pressure to account for the inherent differential pressure drop across the filter. This typically ranges from 20 to 30 psi. All side stream filters have a maximum working pressure; sand filters have a threshold of 80 psi, while mechanical filters, such as screen filters, can operate up to 150 psi. Systems require cleaning of filters or holding chambers to remove debris and particles that are trapped in filters.

Filters are rated by the size of particles that can be removed, measured in microns. Suspended solids in cooling towers typically range in size from 1 to 50 microns as shown in Table 1. In general, 90% of the particles in cooling towers are smaller than 10 microns (Bobby et al. 2001). However, for mechanical filtration the smaller numbers of larger particles are of more concern than the large number of smaller particles which are often bacteria removed by disinfection rather than filtration (BAC 2012), or micron and sub-micron sized suspended solids which can be treated and removed by chemical treatment. Side stream filtration systems are generally sized to filter from 3 to 10% (up to 20%) of the overall system flow. Filters are selected based on the percent of flow that the side stream filtration system is designed to handle. For example, in a cooling system with a recirculation rate of 1500 gpm, a filtration system sized to handle 10% of the recirculation rate would be sized to handle 150 gpm.

Table 1. Relative Size of Common Cooling Water Contaminants (McDonald 2009)

Particle	Microns
Sand	100 to 2,000
Pollens	10 to 1,000
Mold Spores	10 to 30
Bacteria	3

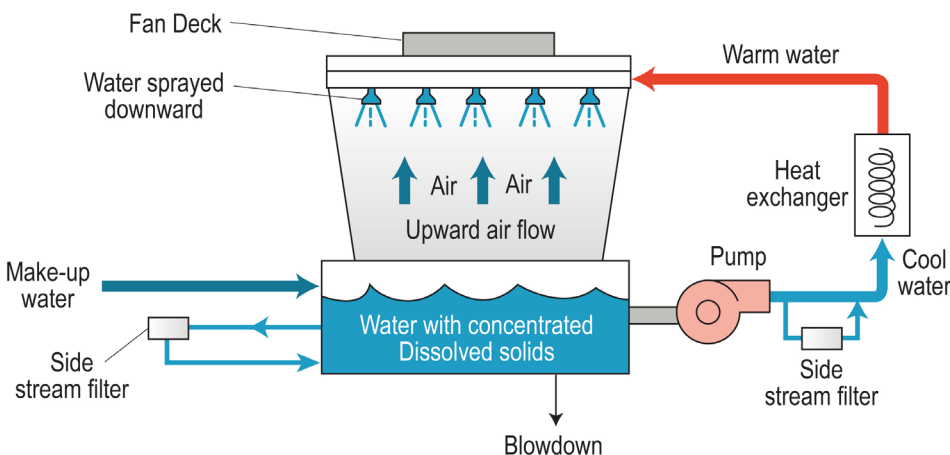


Figure 2. Cooling Tower with Side Stream Filtration Examples

Side stream filtration increases water and energy efficiency and reduces cost, as described below (Latzer 2012; BAC 2012).

- Reduction in water consumption:** Demand for makeup water in cooling towers is decreased with an increase in the system’s cycles of concentration. Essentially, higher cycles of concentration mean that water is being recirculated through the system longer before blowdown is required. Less blowdown reduces the amount of makeup water required in the system, resulting in water savings.
- Reduction in energy consumption:** Side stream filtration reduces the likelihood of scale and fouling on the heat exchangers. Even the smallest layer of scale or fouling on heat exchange surfaces can reduce the rate of heat exchange, forcing the system to work harder to achieve the required cooling.
- Reduction in chemical use:** A side stream filtration system can remove suspended particles, reducing the need for additional chemical treatment such as dispersants and biocides.
- Lower maintenance cost:** Traditionally, cooling towers are cleaned by draining the tower and having the sediment removed mechanically or manually from the basin or sump. Cooling systems that are cleaned via side stream filtration routinely provide longer periods of continuous operation before being taken offline for required maintenance.
- Improvement in productivity and reduction in downtime:** When a cooling system is fouled or has scale buildup, production may be slowed due to inefficient heat exchange equipment. In some cases, the cooling system and heat exchange equipment may need to be taken offline for repairs, decreasing production.
- Control of biological growth:** Biological growth control and reduction can mitigate potential health

problems, such as those caused by *Legionella*. ASHRAE Guideline 12-2000 has basic treatment recommendations for control and prevention, stating that the key to success is system cleanliness.

Technology Applications

The following are applications where the addition of a side stream filtration system can improve the water and energy efficiency of the system.

- Systems for which the primary source of makeup water is a surface or other unclarified source.
- Systems with difficult biological problems, even with the presence of a good biocide program.
- Systems that are susceptible to fouling due to either the nature of the application or the environment in which they operate.
- Systems where scaling deposits cause a loss of heat transfer.
- Systems with high levels of solids buildup in the sump due to dirt and debris deposited by windy conditions.
- Systems in which the heat exchangers require frequent mechanical cleaning.

System Options

There are generally four system options for side stream filtration: centrifugal separators, screen filters, disc filters, and sand filters. For all of these options, the key performance elements to consider in the filter system are the particle removal level, self-cleaning function, ease of operation, and water loss from back wash. These characteristics were assessed for the four basic types of side stream filtration systems. An overview of their performance characters is summarized in Table 2 and more detailed information on each system type is presented in the following sections.

Table 2. Side Stream Filtration System Characteristics

Filter Type	Particle Removal Level	Self-Cleaning Features	Maintenance and Part Replacement	Water Loss from Backwash
Centrifugal Separators	40-75 microns, fine to coarse inorganics with a specific gravity of 1.62 or greater	Purge collected solids from the collection chamber	Purge components only – periodic inspection and servicing	No water loss due to back washing. Water may be lost during the purging of the particle chamber
Automatic Screen Filter	Down to 10 microns	Automatic backwash by using a rotating suction scanner assembly	Regular maintenance may be required because of moving parts that enable automatic backwash	Requires much less water than other self-cleaning filters that utilize backwash cycles
Plastic Disk Filter	Down to 10 microns	Automatic backwash through releasing grooved discs and reversing water flow to wash collected solids off the discs	Consumable discs can require frequent replacement	Requires much less water than other self-cleaning filters that utilize backwash cycles
Pressure Sand Filter	Down to 10 microns	Automatic backwash, once a day or on pressure drop as needed	Requires regular inspection of sand media and electromechanical parts, and periodic replacement of sand media	Requires significant water for backwashing
High Efficiency Sand Filter	Down to 0.45 microns. Best for fine, light particles; avoid heavy coarse particle applications	Automatic backwash features, requires less time and water than other sand filters	Sand media must be monitored and periodically disposed and replaced	Requires more backwash water than centrifugal separators, automatic screen, and disc filters; but about eight times less water than other sand filters

Centrifugal Separators

Centrifugal separators remove solids from water by the centrifugal force developed as water passes through the device. The technology is simple in design. Separators are fed high-velocity raw water to develop the circular flow pattern that produces the centrifugal action. This centrifugal action causes heavy solids that are suspended in the water to migrate toward the separator’s sidewalls and downward, into a solids holding chamber. Cleansed water rises through the vortex and is returned to the system through an outlet at the top of the separator. Solids collected in the holding chamber are either periodically or continuously purged from the collection chamber (Figure 3).

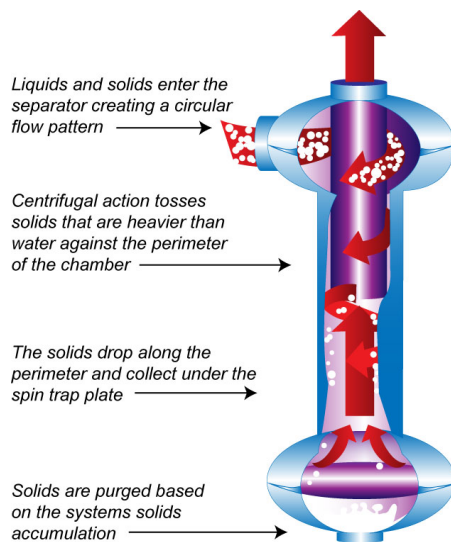


Figure 3. Centrifugal Separator Schematic

The capacity for solids removal is a function of particle density, size, and shape, and device design. Centrifugal separators are best used for and most efficient at separating large, heavy particles. A centrifugal separator requires little maintenance and infrequent replacement because it does not trap particles that clog or damage its system. Therefore, centrifugal separators tend to be more economical than other filtering systems with the same filtration efficiency, but are just as effective at removing suspended solids. (Griswold Filtration 2008)

Automatic Screen Filters

An automatic screen filter, also known as a self-cleaning screen filter, is a type filtering system that uses system pressure

to clean itself. Cooling water enters the filter through an inlet, then passes through a rigid cylindrical screen from the inside out, causing particles larger than the openings of the screen to accumulate on the inside surface and form a filter cake. Filtered water leaves the filter body through the outlet. The buildup of the filter cake inside the screen causes a difference in pressure between the inlet and outlet of the filter. A controller monitors the pressure in the filter and opens a flush valve when it senses a differential pressure threshold has been exceeded. When the flush valve opens to atmosphere, the difference between the higher pressure of water inside the filter and the atmosphere outside the filter body causes high suction forces at the openings of each of the suction scanner nozzles. The 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 forcing it into the suction scanner and out the exhaust valve to drain (Figure 4).

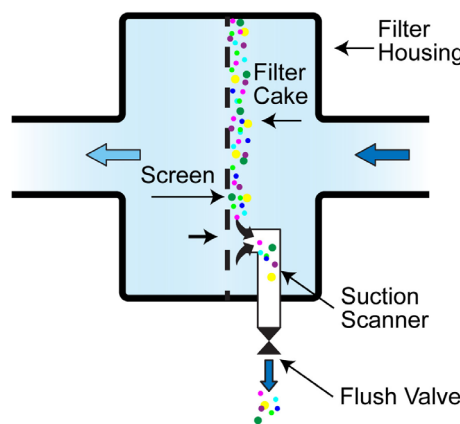


Figure 4. Automatic Screen Filter Schematic

The driving mechanism of the filter rotates the suction scanner assembly at a slow, fixed rotation while simultaneously moving the scanner linearly at a fixed speed. The combination of the rotation and the linear movement gives each suction scanner nozzle a spiral path along the inside surface of the filter screen, which allows the nozzles to remove the filter cake from every square inch of the filter screen. The cleaning cycle usually takes less than 1 minute. The total volume of water used for cleaning is small, usually less than 1% of the total flow.

Automatic screen filters are unique in that the self-cleaning cycle does not require the entire system flow to stop and reverse. Therefore, unlike many other types of filters, the self-cleaning cycle of these filters does not interrupt system flow during the rinse cycle. In addition, automatic screen filters provide a two-dimensional, discrete opening that positively removes particles that are larger than the pore size of the screen based on size alone, regardless of other characteristics such as particle density, shape, or particle materials. Self-cleaning screen filters are used in a variety of applications where continuous water flow is crucial, including accelerator or reactor cooling, hospitals, power generation, climate controlled research facilities, and manufacturing processes that require continuous cooling. This technology is relatively inexpensive for the high flow rates it offers (BAC 2012).

Plastic Disc Filters

This technology uses plastic discs made of polypropylene that are stacked together under pressure and grooved to filter particles of specific micron sizes. Each disc has etched grooves in a slightly different pattern array between the top and bottom of the disc. When multiple discs are stacked and centered around a skeletal cylindrical structure, called a “spine,” the discs form a hollow cylinder with the ends of the grooves exposed to both the inside and the outside surfaces of the cylinder (Figure 5). The different groove patterns of the stacked discs create intersections of different sizes to trap particles when cooling water passes from the outside to the inside of the hollow

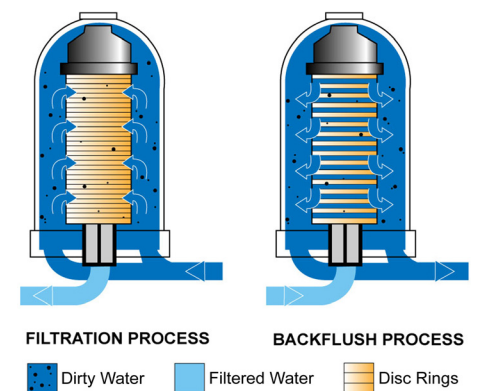


Figure 5. Plastic Disc Filters

cylinder. As particles are captured within the depth of the disc stack, a pressure differential is created. Backwash is initiated when the preset pressure differential is achieved. The stack pressure is relieved and the filtered water is forced through the disc stack in reverse through several nozzles within the disc stack spine. These nozzles create a tremendous amount of turbulence that cleans the discs very effectively in 10 to 20 seconds (Prochaska 2002).

Disc filters can remove both solids and organic particles effectively. These filters also use much less water than other types of self-cleaning filters for backwash cycles, and tend to have relatively lower installation and operating costs compared to other filters with equivalent filtration rates. Disc filters can backflush multiple filters sequentially, and because the backflush cycle is sequential, the filtration process is seldom interrupted. Triggered by differential pressures or timing intervals, or a combination of both, the self-cleaning process is fully automatic, requiring little maintenance.

Sand Filters

Sand filters are a common type of side stream filtration system. Sand filters direct fluid into the top of their tank(s) and onto the surface of a bed of specified sand and/or other media. As the cooling water flows through the bed of sand media, suspended solids and other particles are captured within the upper layer of media. Sand filters are usually very efficient at removing the extremely fine and low density particles that cooling towers scrub from the air. Therefore, they generally have very high filtration rates. Sand filters tend to be more expensive and larger than other types side stream filtration systems with equivalent filtration rates (Melancon 2004). There are typically three types of sand filters, pressure sand filters, high efficiency sand filters, and gravity sand filters. However, gravity sand filters are rarely used for cooling tower systems; they are therefore not discussed in this fact sheet.

A feature of sand filter design that should be considered is the capability of supplemental chlorination during backwash or routine maintenance. The filter medium in many types of sand filters coupled with the increased temperature of the recirculating cooling water can support biological activity. Supplemental chlorination is an effective strategy to reduce increased biological growth in the filter medium, and therefore in the cooling water as well. In short, sand filters provide excellent removal of suspended solids, but size, expense, and maintenance concerns are considerations when selecting this technology.

Pressure Sand Filters

Pressure sand filters are one of the most common side stream filtration systems and are used in many facilities. A pressure sand filter consists of a pressure vessel and several layers of multi-media filters. A coarser filter media is located on the top layer, with layers of decreasingly granulated material down to the fine media at the bottom. A layer of gravel is included on the bottom layer to prevent finer sand media material from migrating through the drain (Figure 6). Typically, these systems are effective at filtering particles of sizes between 15 and 20 microns.

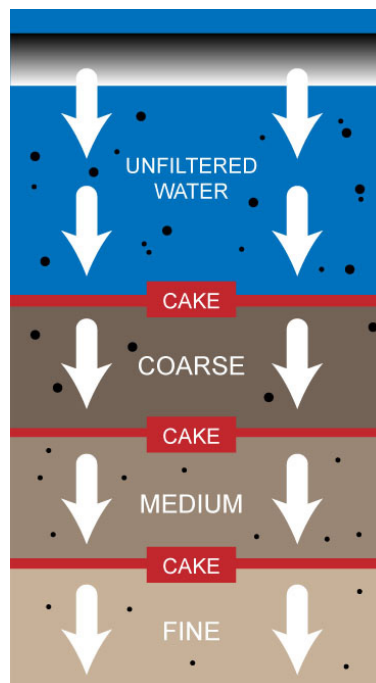


Figure 6. Pressure Sand Filters Schematic

For pressure sand filters, the backwash requirement is relatively high and an external source of backwash water is needed. Clean, treated city water or clarified, chlorinated water are the preferred water source for backwash, which typically takes 10 to 15 minutes per backwash. Backwash is initiated by either a pressure differential switch measuring the incoming and outgoing pressures or an adjustable timer. A backwash with a clean, chlorinated source is recommended at least once per day to maintain media efficiency and to prevent microbiological activity.

High Efficiency Sand Filters

This type of filter is similar to the pressure sand filter in that sand is used as the filtration media. However, the media layer order is reversed, with extra fine sand as the top layer and layers of gradually coarser sand down to the bottom layer (Figure 7). Raw water is introduced to the pressure vessel, with an angled inlet creating a turbulent and spinning flow across the media bed, called a “vortex.” The particles in the vortex collide with the fine sand barrier and with the vessel wall. The collision causes the particulates to fall out tangentially and coat the media bed and vessel with a filter “cake.”

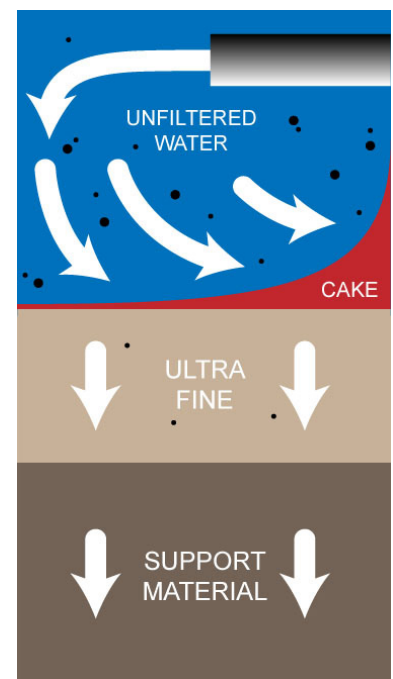


Figure 7. High Efficiency Sand Filters Schematic

High efficiency sand filter technology, therefore, is differentiated from conventional pressure filters because particles are captured on the surface of the filter medium instead of penetrating the filter media as in conventional pressure filter technology. This provides two advantages: (1) filtration can be achieved down to 0.45 micron even on a clean media bed because of the use of the extra fine sand media and (2) backwash requirements are low because particles are not captured deep inside the filter media. Only approximately 50% of the designed flow through the high efficiency filter is required for a backwash that takes between 5 and 8 minutes. This is compared to 150% of the design flow requiring 15 to 20 minutes for pressure sand filters.

These filters operate efficiently in a smaller installation footprint. High efficiency filters can filter 18 gallons of water per square foot of media surface, compared with 8 to 10 gallons per square foot of conventional pressure filters. This filter footprint difference can be very important for selecting equipment in mechanical rooms.

System Implementation Considerations

When considering a side stream filtration system, there are several key parameters that are important to weigh including the level of particle removal, filtration sizing, installation methods, and cost and water savings potential. Carefully examine the following features to properly specify the proper side stream filtration system for the appropriate application:

- Particle size distribution analysis
- Filtration sizing
- Installation methods
- Filtration design features
- Financial analysis

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