

# TODAY'S TECHNIQUES FOR HEAT EXCHANGER PROTECTION VIA PARTICLE FILTRATION

Kathy Colby

1365 North Clovis Avenue, Fresno, California 93727 USA [kathyc@lakos.com](mailto:kathyc@lakos.com)

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### ABSTRACT:

Particle contamination of evaporative cooling loops can be created by a variety of sources, including airborne entry, make-up water, corrosion by-products, and precipitated mineral development. This particle matter commonly fouls heat exchangers, reducing heat transfer efficiency, causing excessive shutdown/cleaning routines, and posing health and safety concerns. It is important to first identify and define the particle contaminants before applying a filtration technique to effectively remove those contaminants. It is also equally important to select a filtration technique with an understanding of its proper placement, sizing and solution potential.

Particle analysis must include an awareness of not only what type of particles are in the cooling water, but also what particles are most responsible for the fouling and/or lost efficiency of the heat exchanger. An understanding of particle type will greatly determine the proper type of filtration to apply. Understanding the issue of particle size will determine the level of filtration necessary to achieve the desired protection of the heat exchanger. In essence, it is not always critical to remove the very finest sizes of all types of particle matter in order to assure proper protection of the cooling water system and heat exchangers.

With the knowledge of what contaminants must be filtered to achieve heat exchanger protection, a review of the popular filtration methods helps identify the proper devices for a given application. Then, using an objective set of selection criteria, the most appropriate filtration system can be determined. Performance and price are obvious issues, but there are several other key factors to consider when the goal is long-term overall savings.

The techniques for filtering cooling water each promise a different level of success as it relates to protecting heat exchangers. Understanding the basic installation scheme for each technique unveils that technique's ability to remove particle contaminants. Over the years, experience and performance have produced a

comparative view of various techniques that can help grade the potential solution capability of each technique. An in-depth review of the techniques will identify advantages and limitations.

## TYPES OF PARTICLE CONTAMINATION: WHAT CONTAMINANTS ARE REALLY CAUSING YOUR COOLING TOWER PROBLEMS?

Whether from airborne sources, make-up water, precipitated minerals or created by the heat exchange process, cooling systems naturally take on unwanted contaminants and suffer in many ways. When seeking the proper filtration to alleviate problems with unwanted contaminants in the re-circulating water loops of an evaporative cooling system, there are many choices and each has its own distinct capabilities and limitations. It is best to start with the system problems and to determine the contaminants responsible for those problems. Then the proper filtration can be selected.

## IDENTIFY AND DEFINE THE CONTAMINANTS: WHAT ARE THE PROBLEMS?

The most common misconception is that the contaminants are the actual problem. In fact, the malfunctioning of downstream equipment caused by the contaminants is the actual problem. So the focus should be on what elements of the system are not working in accordance with the design specifications or are causing problems/costs associated with performance or operating conditions.

By design, heat exchangers create changes in temperature in order to affect heat transfer. A by-product of that process may be the precipitation of minerals in the water, encouraging the creation and accumulation of particle contaminants that can adversely affect thermal conductivity (actually insulates the relative surfaces to retard effective heat transfer), restricting flow and/or plugging small orifices. This, of course, causes deviations from design conditions of such equipment and limits a heat exchanger's performance. Ultimately, downtime becomes necessary to clean the heat exchanger.

When examining a cooling tower regarding problems due to particle contamination, a few issues become visible. As unwanted particle contaminants flow

through a system, they are naturally prone to clog small orifices, especially the nozzles and/or distribution headers that disperse water into a cooling tower's fill area. Clogged nozzles upset the balance of flow and create uneven/inconsistent wetting of the fill, which leads to lost tower efficiency and the eventual need for system shutdown and maintenance.

Build-up of contaminants on the fill itself can also be problematic, creating increased bacteria potential and an actual threat of collapsing the fill. An effective water treatment program can help control this problem, but if the source of the contaminant is not eliminated, treatment often must be increased to offset this increased threat and even then, excessive particle matter will build up to troublesome proportions.

The tower basin or remote sump provides a perfect environment for unwanted particle matter to settle and accumulate. The wet and warm conditions of the basin or remote sump encourage bacteria growth. The build-up of solids provides nutrients and protection for the bacteria from the biocide, increasing biological problems in the basin or sump and subsequently throughout the entire system. This type of habitat increases the risk of health hazards such as Legionnaires Disease. Water treatment is very important, but contaminant build-up at the bottom of a basin or sump provides a real challenge to chemical treatment – a challenge that chemical treatment alone will not be able to overcome. In fact, water treatment can only control the effects of this kind of problem, but does not serve to eliminate the habitat that promotes the proliferation of bacteria.

According to the ASHRAE Guidelines 12-2000 (page 3), when legionellae are present in aquatic environments, there are multiple factors that control the risk of infection – such as:

- conditions favorable for amplification of the organism
- a mechanism of dissemination
- inoculation of the organism at a site where it is capable of causing infection
- bacterial strain-specific virulence factors
- the susceptibility of the host

Water temperatures of 25-42 degrees Celsius (77-108 degrees Fahrenheit) provide an optimal environment for legionellae growth, especially if the water is still, contains scale and sediments, biofilms, and/or amoebae. Also, certain materials affect the growth of legionellae favorably – like natural rubbers, wood, and some plastics. Copper, on the other hand, has been discovered to inhibit the amplification of legionellae.

As indicated by the factors mentioned above, a good water treatment program is crucial to prevent legionellae. The result of an effective water treatment

program is a heat transfer fluid that allows the associated equipment to function optimally. If a water treatment program is effective, then equipment fouling should be reduced substantially, which in turn will make the entire operation more efficient, as well as prolonging the system life.

Dr Barry Fields<sup>1</sup>, Chief of Respiratory Disease Control for the U.S. Center for Disease Control and Prevention recently confirmed that a build-up of as little as 1/16<sup>th</sup> of an inch (1.59 mm) can cause the breeding of bacteria in a cooling tower environment. This solids build-up also presents the conditions leading to under-deposit corrosion on the sump floor, ultimately causing leaks in the basin itself.

### **PARTICLE ANALYSIS:**

Settleable solids, such as sand, silt, grit, scale, rust and precipitated minerals are certainly problematic, since they are large enough to clog nozzles and small orifices and heavy enough to settle in tower basins and remote sumps. These solids are routinely present in sufficient concentrations to create problematic conditions throughout a cooling tower system.

Suspended particle matter, such as leaves, grasses, cottonwood seeds, bird feathers, insects and organic matter can, in excess concentrations, cause clogging of nozzles and small orifices. This type of particle is also of concern to tower fill. Since these contaminants do not settle, it is unlikely that they will create problems in tower basins or remote sumps, but potentially cause problems downstream at the heat exchangers.

Particle size is the most misunderstood issue within the whole process of particle analysis. The most common misconception is that contaminants as small as 0.5 microns or less are not only the predominant numerical contaminants in cooling tower water, but also most responsible for the majority of cooling tower problems. Yet the Water Quality Association – an authority on drinking water standards in the U.S. - recognizes that any contaminants below 5 microns in size are most commonly identified as bacteria, a contaminant that is not removed by filtration, but by disinfection.<sup>2</sup>

Even if such small particles were the predominant number of particles in a system, the real focus ought to be the total volume that the particles represent. The chart below offers a comparative and hypothetical example, taking a sample of one trillion particles, with given portions of that sample in each of

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<sup>1</sup> ASHRAE Guidelines 12-2000

<sup>2</sup> ASHRAE Guidelines 12-2000

several particle sizes. As can be seen, if only 15% of the total numerical count of particles is greater than 10 microns, those 15% represent over 99% of the total volume. In an actual cooling water loop, there may be many times this amount, but the relative ratio is still valid and important to consider in terms of which contaminants to be most concerned about. This fact should be considered when determining the particles that are capable of fouling a heat exchanger's small orifice, clogging a nozzle or accumulating in a cooling tower's fill, basin or remote sump.

Table 1: Particle size vs volume

| Size of Particle  | Quantity of Particle         | Total Volume                   |
|-------------------|------------------------------|--------------------------------|
| 5 microns         | 212.5 billion particles      | 14.58 cm <sup>3</sup>          |
| 3 microns         | 212.5 billion particles      | 3.11 cm <sup>3</sup>           |
| 1 micron          | 212.5 billion particles      | 0.11 cm <sup>3</sup>           |
| 0.45 micron       | 212.5 billion particles      | 0.0098 cm <sup>3</sup>         |
| <b>Sub-total:</b> | <b>850 billion particles</b> | <b>17.83 cm<sup>3</sup></b>    |
| 10 microns        | 37.5 billion particles       | 21.30 cm <sup>3</sup>          |
| 25 microns        | 37.5 billion particles       | 303.16 cm <sup>3</sup>         |
| 50 microns        | 37.5 billion particles       | 2459.70 cm <sup>3</sup>        |
| 75 microns        | 37.5 billion particles       | 8260.72 cm <sup>3</sup>        |
| <b>Sub-totals</b> | <b>150 billion particles</b> | <b>11044.88 cm<sup>3</sup></b> |

The table above, representing a sample of one trillion particles in a range of sizes, shows that even a relatively small number of particles 10-75 microns in size can represent a very large total volume of particles.

### POPULAR FILTRATION METHODS:

It is important to start with identifying what equipment/components need protection from the contaminants, e.g.: the heat exchangers, the cooling tower basin or remote sump, the tower fill and/or the distribution headers/nozzles. The second step should assess the costs associated with the problem: increased energy and chemical costs, downtime, cleaning, repairs and/or replacements, outside services, and overtime labor and maintenance. The anticipated costs will become important when the cost of the problem is being compared to the cost of the solution.

In general, there are five approaches that are widely accepted as the techniques for controlling solids in an evaporative cooling system. Each technique addresses the problem in a different way and has its own distinct value and benefits.

### Full Stream Filtration:

With full-stream filtration, the filter is installed at the system's supply pump's discharge (from the tower basin or remote sump), prior to the heat exchangers/chillers. The filter is sized according to the full flow of the pump, filtering all the water that passes on to the heat exchanges/chillers – which is the primary value of this approach. It is estimated to increase the operating cycle of the heat exchanger by ten times before servicing requirements appear (based on experiences with users who have kept good “before and after” records). This approach does not directly address the problem of basin/remote sump solids accumulation. Although effective filtration can reduce overall solids concentration, the tower environment itself does attract and create unwanted solids that can settle in the basin and pass on to the heat exchanger.

### Side Stream Filtration:

A typical side stream filtration diverts approximately 10-20% of the full-stream flow through a filter and back into the full-stream flow prior to the heat exchangers/chillers. Redirecting the side-stream flow back to the pump suction is not recommended, since that would reduce the flow to the heat exchangers or require an increase in the pump output. The logic of this technique is filtering the water at a rate greater than the anticipated input of contaminants. Lower side stream percentages are occasionally employed, but not recommended. Location (such as near open fields or windy, dusty situations) and seasonal conditions (such as pollen, harvesting or spring blossoming) provide for higher contaminant potential, suggesting a higher percentage side stream to overcome these conditions. This approach is estimated to increase the operating cycle of a cooling tower's heat exchangers by 3 times before servicing requirements become acute (based on experience with users who have kept good “before and after” records). This technique is used most often when the full stream flow is extremely high, causing full stream filtration to be financially infeasible. Like full stream filtration, this technique does not address the problem of solids accumulation in the tower basin or remote sump.

### System Turnover:

System turnover is often misunderstood as side stream filtration or basin cleaning. System turnover requires the calculation of the total volume of water in the cooling loop (in the basin/sump, piping, heat exchangers, etc) and a once-an-hour rate of turnover (total water volume divided by 60 = USGPM/(m<sup>3</sup>/h) flow rate). This flow rate is often times very similar to that of side stream filtration, but accounts for greater system fluid volume, due to multiple factors, such as extensive piping, enlarged basin size, etc. The estimated increase in the operating cycle of a heat exchanger is three times before the servicing requirements become necessary (based on experiences with users who have kept good “before and after” records). Like the techniques mentioned previously, this approach does not address the issue of solids accumulation in the tower basin or remote sump.

### **Basin Cleaning:**

Compared to the techniques above, filtration directed specifically at the control of solids accumulation in the cooling tower’s basin or remote sump is new to the HVAC industry. However, its success and value place it among the most popular filtration approaches today. When applying basin cleaning as a means of filtration, water is drawn from the tower basin/sump to the filter package and directly back to the tower basin/sump via a pattern of specialized nozzles to create a directed turbulence of flow designed to influence any settleable particles toward the basin cleaning package’s pump intake. The size of the filter package is based on the size of the cooling tower’s basin or remote sump and a rule of thumb is “1 gpm per square foot” or 0.2 m<sup>3</sup>/hr per 0.1 m<sup>2</sup>. This technique, despite concentrating its effort to the prevention of basin or remote sump build-up and not directly protecting the heat exchanger, nonetheless is expected to increase the operating cycle of a heat exchanger by eight times before servicing requirements become necessary (based on experiences with users who have kept good “before and after” records).

Unlike the previously mentioned techniques, basin cleaning does directly address basin/sump accumulation. Basin cleaning does require the appropriate use of a venturi-like nozzle system to increase the total flow activity without the need for a high volume pump, thereby keeping equipment and pump energy costs to a minimum. These nozzles are known as eductors or HydroBoosters and they increase the flow that passes through them by a factor of 5-6 times, enabling the filter package to use a smaller filter and pump, while still achieving the flow activity necessary to sweep the settleable solids across the basin/sump to the filter package’s pump intake.

An important element to making this approach work effectively is adhering to the flow and pressure requirements (20 psi or 1.4 bar minimum) of the chosen nozzles in order to achieve the necessary flow to sweep the solids in the basin/sump and prevent troublesome accumulation. An inadequate flow/pressure to these nozzles minimizes the flow-increase capability of these nozzles, and reduces the overall flow activity necessary to sweep solids toward the pump intake and into the filter. In essence, with inadequate flow/pressure this method achieves not much more than the equivalent of the system turnover technique described above.

### **Make-up Water Filtration:**

This technique employs a filter at the make-up water intake to keep unwanted particle matter from entering the system. Its value is limited to keeping make-up water contaminants from contributing to the system contaminant problem. Its limitation is that most solids typically come from the incoming airflow and the creation of solids via the evaporation-precipitation process. To date, no protection factor has been identified with this approach, although a water supply with significant sand, silt or organics could certainly create equally significant problems if not properly filtered.

### **MOST APPROPRIATE FILTRATION SYSTEM (WHAT SYSTEM FOR WHAT PURPOSE):**

With the knowledge of what parts of the system need protection and what contaminants need to be removed to achieve that protection, filter selection now can be assessed on the basis of an objective set of criteria for effective comparative evaluation. Product features and benefits become important only in the context of need. Application criteria and user needs become the real issues. The process is now logically controlled by the buyer, not by the seller.

It is important to first determine what the filter will and will not remove, and to discover limitations and complications, as well as an assessment of the maximum particle load that the filter is capable of handling. Centrifugal separators, for example, remove settleable solids, but not lightweight contaminants. Sand filters, on the other hand, are good for removing organic and lightweight particles, but have difficulties with settleable particles because once those settleable particles are captured on the sand media bed it is difficult to backwash and remove heavy particles from the sand filter. Self-cleaning screens and disc filters remove both types of materials, but are limited to lighter concentrations and may experience problems when multiple contaminants must be removed from the screen surface.

The range of pressure loss that the filter will experience has to be determined, and it also has to be determined if that range is acceptable to the operating parameters of the system pump and downstream requirements of the overall system (heat exchangers, nozzles, etc). Separators operate at a steady pressure loss, related directly to the system flow. Sand filters, screens, disc filters and other barrier-type filters each start with relatively low pressure losses, but many reach very high levels or require frequent backwashing to satisfy system pressure requirements.

It is important to determine whether water loss is an issue and determine how much water is lost per purging/cleaning/backwashing cycle. Separators require periodic purging with limited water loss, which is typically set on a timer schedule. Sand filters and self-cleaning screens use pressure differential to trigger backwashing cycles, and may flush significant water with each cycle.

An important issue associated with filtration selection is the question of what parts will require periodic replacement and at what frequency and cost. Separators have no moving parts and require no replacements, except for the automatic purge valve (ball, motor). Sand filters and self-cleaning screens have multiple moving parts with wear factors. Media sand or screens will require periodic replacements. Separators do not require system flow interruption when purging. No disassembly routines are required. Sand filters, screens and disc filters will divert system flow for cleaning and must be opened/serviced on a routine basis.

#### **PAYBACK LOGIC OF FILTRATION:**

It is often said that cost saving measures are always "in the budget," but usually those expenditures are labeled as maintenance, not cost saving measures. The maintenance budget is most often much lower than the actual cost savings.. Such is often the case with proper filtration for an evaporative cooling water system. The payback value of filtration can be found by calculating the costs associated without filtration and comparing those costs to the costs of the proposed solution. Another way to identify whether filtration can become a solution is to apply the following criteria:

- Reduced maintenance costs (60-90% savings)
- Reduced energy costs (10 % savings)
- Reduced water costs (5-10% savings)
- Reduced chemical costs (5-15% savings)
- Reduced downtime (case-by-case basis)

These criteria can be used as a formula for calculating the basic payback associated with proper filtration. The costs of wear and replacement of the tower and heat exchangers/chillers should be added to these costs, as well

as the damage to pumps, the fouling and repair/replacement of valves and control instruments. This will justify the expenses incurred when budgeting filtration.

The relationship between maintenance and operational efficiency (energy costs) is well known. Often, while attempting to minimize maintenance costs, energy costs are actually increased, yet properly maintained equipment can also minimize energy costs by optimizing system performance. By reducing the contamination of heat exchangers and by improving the chilled water flow rates in all lines, the heat transfer performance and the overall efficiency of all pumps, heat exchangers and other related equipment can be dramatically improved.

Annual costs of fouling include many different components, such as increased maintenance costs, over sizing and/or redundant equipment, special materials and/or design considerations, added costs of cleaning equipment and chemicals, hazardous cleaning solution disposal, reduced service life and added energy costs, increased costs of environmental regulations, loss of plant capacity and/or efficiency, and loss of waste heat recovery options.

#### **CONCLUSION:**

The best type of filtration for protecting heat exchangers depends on a number of variables including particle type, volume of troublesome solids to be removed, and the type of heat exchangers to be protected. In selecting the correct type of filtration for heat exchanger applications, it is important to address the fundamentals of filtration:

1. Identify what equipment needs to be protected
2. Concentrate on removing the contaminants most responsible for the problem
3. Select the most appropriate filter and technique to achieve your desired results.

A good water treatment program with solids filtration is crucial to prevent legionellae. The result of an effective water treatment program is

a heat transfer fluid that allows the associated equipment to function optimally. If a water treatment program is effective, then equipment fouling should be reduced substantially, which in turn will make the entire operation more efficient, as well as prolonging the system life.

The most common misperception is that contaminants as small as 0.5 microns or less are not only the predominant numerical contaminants in cooling tower water, but also most responsible for the majority of cooling tower problems. Yet contaminants below 5 microns are most commonly identified as bacteria, a

contaminant that is not removed by filtration, but by disinfection. The focus should be on the volume that the particles present. If only 15% of the total numerical count of particles is greater than 10 microns, those 15% will represent over 99% of the total volume.

Applying filtration will reduce a variety of costs, such as reduced maintenance costs (60-90%), reduced energy costs (10%), reduced water costs (5-10%), reduced

chemical costs (5-15%), and reduced downtime (case-by-case). These criteria can be used as a formula for calculating the basic payback associated with proper filtration. The costs of wear and replacement of the tower and heat exchangers/ chillers should be added to these costs, as well as the damage to pumps, the fouling and repair/replacement of valves and control instruments. This will justify the expenses incurred when budgeting filtration.