Tech Byte 11: Benefits of Filtration for Open Cooling Tower Systems

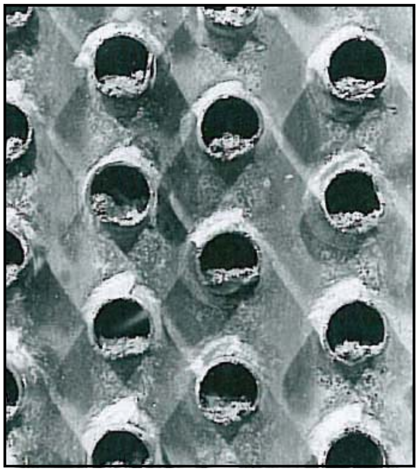
Preventing Localized Corrosion and Improving Heat Transfer Efficiency

The need for filtration of any cooling tower system is somewhat understood and accepted by most building professionals and plant operating engineers. However, for some, that need is finally driven home and acted upon only after the discovery of a serious corrosion problem, pipe deposit problem, or the realization that a lot of cleaning and maintenance is required to sustain the system without filtration. For commercial buildings, the HVAC system represents a major capital expense and is generally the largest consumer of electricity. Proper and regular maintenance, effective water treatment, and filtration of the cooling system are critical in keeping operating costs low and maximizing the service life of the equipment. With all the documented benefits, the reality is that more building managers or process plant operators should preempt potential problems with the installation of a water filtration system.

Picture #1- Interior Pipe Deposits

The filtration need is derived from these significant factors. First, cooling towers operate by inducing contact between outside air and the system water loop, and therefore they act as giant air-scrubbers. Anything that can find its way airborne in the vicinity of the tower can end up making its way into the tower, and in many cases, into the cooling water loop. Second, make up water that is introduced into the tower often has grit, sand, or other solids in it. All of these solids that are introduced into the system flow will contribute to an increase in fouling of heat transfer surfaces, unless they are removed by a filtration device.

Third, the corrosion to system piping, tower basins, and other system components introduces more materials and particulate into the cooling system. All of these different types of particulate, which we will refer to as "deposits", can contribute to significant problems if they are not removed.



Picture #2 - Fouling of Chiller Condenser Tubes

Interior pipe deposits are always the result of some form of corrosion activity combined with captured particulates, organic, or microbiological material that is introduced by the cooling tower or make-up water. As corrosion activity and particulate accumulation continues over time and heavier deposits are allowed to accumulate, chemical activity beneath such deposits develops into different forms, commonly known as "under deposit" corrosion.

Deposits can not only reduce heat transfer efficiency and cause restricting flow problems, but under-deposit corrosion can lead to some significant damage. Under-deposit corrosion occurs when the accumulation of deposits shields the covered surface from the bulk water system. Corrosion occurs on the metal surface due to some inherent or environmental difference between one area on that surface and another. In its more severe form, under deposit corrosion will produce narrow and deep pitting - which may in turn result in advanced pipe failure within 10 years or less.

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Because of the risk of under-deposit corrosion and reduced heat transfer efficiency, debris should be removed to the fullest extent possible BEFORE it is allowed to accumulate in the cooling loop. A moderate to severely scaled system will begin experiencing corrosion as soon as a surface has been covered. A filtration system is designed to continuously filter solids out that pass through it, greatly reducing the amount of solids circulating through the cooling loop.

Fouling Factor and Energy Increase

The main energy consumers in a water-cooled air conditioning system are the chiller, recirculating pumps, tower fans, and air handler fans. In fact, water treatment products and services are a very small fraction of the total utilities bill. Most water treatment programs cost less than the water and sewer costs. The energy costs, for the main energy consumers listed above, can be increased by the presence of fouling or deposition on heat exchange surfaces. Whenever there is a deposit of any type on a heat transfer surface, it retards heat transfer. This is referred to as "thermal resistance" and requires a corresponding increase in energy to overcome it. Major manufacturers of air conditioning equipment generally design condensers and chiller heat exchangers to operate at a maximum "thermal resistance" (fouling factor) of 0.0005. Carrier discusses the relationship of "fouling factors" to "inches of scale" and the resultant increase in energy requirements. Table 1 summarizes this information.

Fouling Factor	Inches of Scale*	Increase in Energy, %
0.0005	0.006	5.3%
0.001	0.012	10.8%
0.002	0.024	21.5%
0.003	0.036	32.2%
0.004	0.048	43.0%

* Scale assumed to produce a thermal conductivity of 1.0 Btu/(hr)/(sqft)/(ºF)

Table 1: Fouling Factor

The thermal conductivity expressed in Table 1 relates to a hardness scale (calcium carbonate) deposit. The actual heat transfer coefficient of any fouling / deposit (scale, slime, dirt, silt, corrosion products) depends on what it is. Certainly any fouling / deposit that contributes a thermal resistance will increase energy consumption and decrease efficiency.

The increase in electrical energy takes place in the compressor. The deposits increase the resistance to heat transfer and cause higher refrigerant gas temperatures in the condenser. The higher refrigerant gas temperatures mean higher gas pressures which require more energy to compress. Therefore an increase in electrical energy results.

Pounds of Steel Lost at Various Corrosion Rates
Calculated Per Year, Per 100 Linear Feet of Schedule 40 Pipe

Pipe Size	Corrosion Rate in Mils Per Year (MPY) 1 MPY	5 MPY	10 MPY	15 MPY	20 MPY
2	2.2	11.1	22.2	33.4	44.6
4	4.3	21.5	43.1	64.7	86.4
6	6.5	32.4	64.9	97.4	129.9
8	8.5	42.6	85.3	128.1	170.9
10	10.7	53.5	107.1	160.7	214.4
12	12.8	63.8	127.6	191.5	255.4
24	24.2	120.9	241.9	363.0	484.1

Table 2

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Corrosion Induced Deposits

Picture #3

Advanced corrosion of steel piping systems has become a serious and expensive problem to many facility managers and plant engineers. To illustrate this point, take for example a typical commercial building property of 33 floors, having a cooling tower at the roof and a 5,000 ton refrigeration plant in the basement. We can estimate approximately 1,000 linear feet of 24 in. supply and return piping in service. From Table 2 on the previous page, based upon a moderate 5 MPY corrosion rate commonly found today, we can estimate that approximately 1,210 pounds of steel will be distributed into the system for ***EACH YEAR*** of service due to corrosion losses.

In its oxidized form, steel produces approximately ***20 to 25 times*** its original volume in iron oxide or rust product. Without filtration, this by-product is often found in horizontal lines and at low flow areas - often accumulating in sufficient volume to produce under deposit corrosion, heat transfer loss, and eventually flow rate problems.

Picture 3 is an example of a 10 year old, 12 in. condenser water line with a buildup of "*tubercular*" deposits along its bottom. Without effective filtration and other preventative steps, however, such deposits are virtually inevitable.

Cubic Feet of Iron Oxide Deposits Produced
Calculated Per Year, Per 100 Linear Feet of Schedule 40 Pipe

	Corrosion Rate in Mils Per Year (MPY)				
Pipe Size	1 MPY	5 MPY	10 MPY	15 MPY	20 MPY
2	0.1	0.5	0.9	1.4	1.8
4	0.2	0.9	1.8	2.6	3.5
6	0.3	1.3	2.7	4.0	5.3
8	0.3	1.7	3.5	5.2	7.0
10	0.4	2.2	4.4	6.6	8.8
12	0.5	2.6	5.2	7.8	10.4
24	1.0	4.9	9.9	14.8	19.8

Table 3

Table 3 provides an estimate of rust related debris created by the oxidation of the metal lost, and shows that in general, a tremendous volume of corrosion product is produced. Using the same 33 floor office building as an example, we can estimate that as much as 50 cubic feet of rust and iron oxide deposits will be created from the 1,210 pounds of steel rusted away for ***EACH YEAR*** of service. Over a 30 year history, a significant volume of particulates will be produced to create various secondary operating problems. Again, effective water filtration can reduce the amount of deposits that can accumulate in the cooling loop.

For condenser or open process water systems, alot of this corrosion product will be lost in the cooling tower blowdown, but without filtration, some will settle in the tower basins and condenser heads, and some will remain attached to the pipe wall surface. Not only is the structural integrity of the piping itself threatened by excessive corrosion, but the resulting corrosion products generally cause secondary problems in the form of lost heat transfer, biological fouling, microbiologically induced corrosion (MIC), clogged pipes and abrasive wear to pump seals and components.

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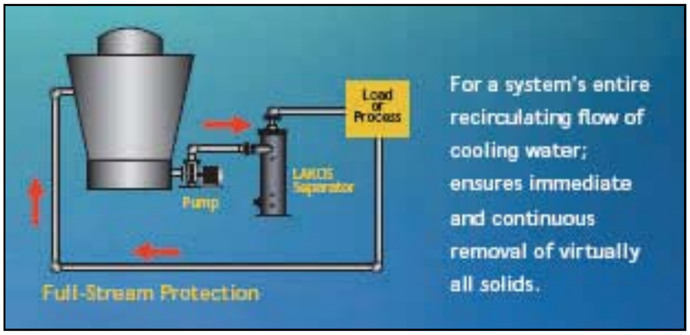
Filtration Overview:

With all of this in mind, the first major consideration should be whether to install full flow or side stream filtration (see pictures 4 and 5). Without debate, any major deposit accumulation problem is best attacked by full flow filtration.

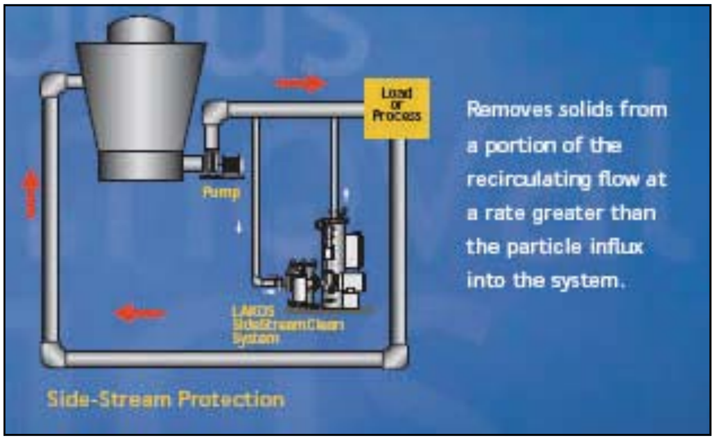
Full flow or high capacity filtration units will capture particulates they are designed for on their first pass, whereas side stream units can capture only a 10% or lesser volume. With full flow filtration, the water has no alternative but to enter the filtering device, whereas with a side stream filter, only a small percentage of that water is captured.



Picture #4 - Full-Flow Filtration

For side stream units, therefore, installation design becomes critical. A poor installation and piping layout, and specifically the wrong take-off point from the main line to the filter inlet, can make any side stream filtration unit almost useless. Conversely, the well designed installation of a side stream unit can often offer outstanding results.

Now that the value of a filtrations system is understood, what is the preferred filtration option for cooling tower systems? Many types of filters exist, and each offers different performance characteristics, costs, and effects on the tower loop. Common filter types are separators, sand filters, cartridge filters, or bag filters just to name a few.



Picture #5 - Side-Stream Filtration

Filtration Objectives:

To determine the ideal filtration solution for a given application, consideration must be given to some specific filtration objectives that can vary from customer to customer. Some of these considerations include:

- Water clarity - For cooling tower loops, creating sparkling, crystal-clear water is not necessarily the objective. The objective is to remove deposits, not polish the water to drinking water standards.
- Incorporation of a filtration solution that is very efficient at removing particulate commonly found in cooling tower loops
- Efficient operation with the least amount of negative impacts on other loop components
- Limitation of on-going maintenance required to support the filtration system
- Reduction of water usage or loss attributed to the filtration system
- Operational reliability of the filtration solution
- Ensuring the filtration solution has the lowest cost of on-going ownership

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Separator systems, such as those manufactured by Lakos Corporation, offer all of these performance and maintainability benefits. Figure #1 on the following page shows a Lakos separator and how it works. The next question is, how does it meet the filtration considerations listed above?

In regards to removing deposits efficiently, the Lakos separator is very effective. In a single pass through the separator, given solids with a specific gravity of 2.6 and water at 1.0, performance is expected to be 98% of 74 microns and larger. Additionally, particles finer in size, heavier by specific gravity and some lighter by specific gravity will also be removed, resulting in an appreciable aggregate removal of particles (up to 75%) as fine as 5 microns. In a recirculating system, 98% performance is predictable to as fine as 40 microns (given solids with a specific gravity of 2.6), with correspondingly higher aggregate performance percentages (up to 90%) of solids as fine as 5 microns. The Lakos separator is very effective on removing the types of particulate that can lead to under deposit corrosion.

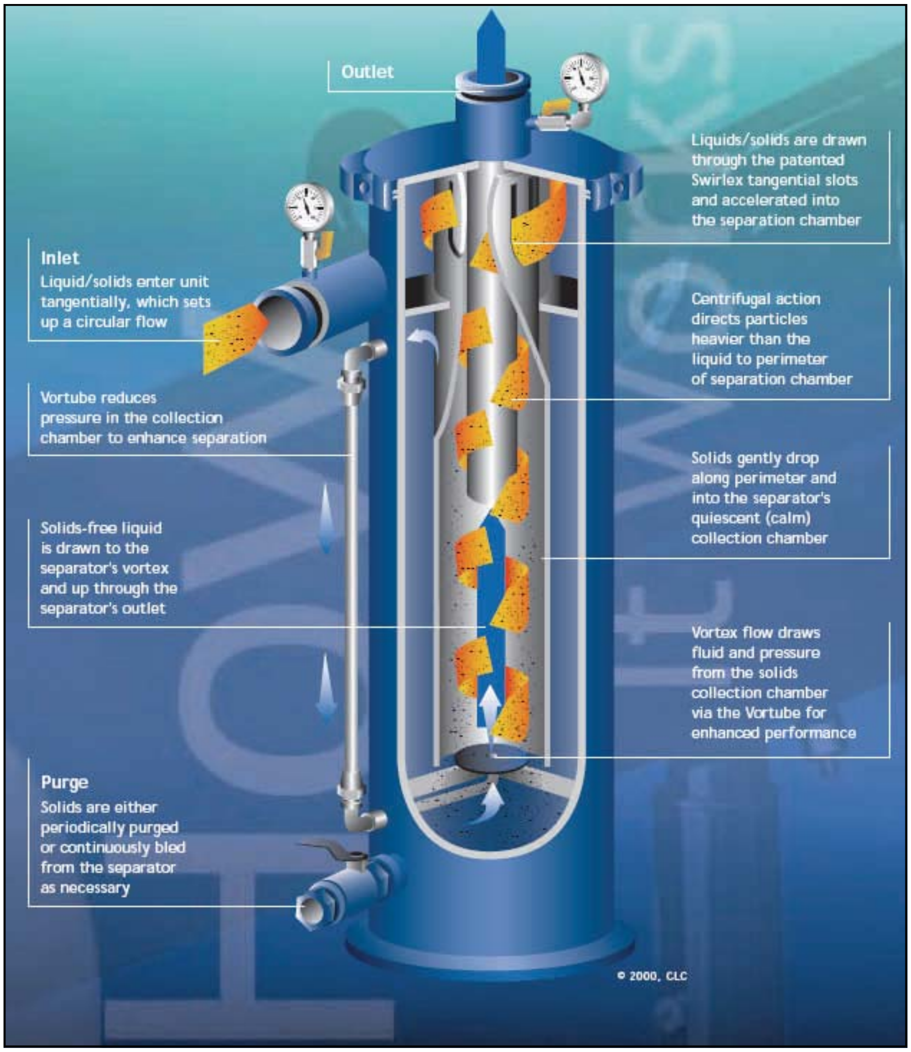

Figure #1—Separator with Auto-Purge

Separators eliminate the complication of system level design that are often encountered with other filtration solutions. Lakos separators operate continuously (no fluctuations) at a steady pressure loss of only 3-12 psi., independent of solids loading. This compared to screens and barrier filters, which build-up to very high pressure losses when they load up.

In regards to maintainability, the separator has two options for how it rids itself of the solids it removes from the tower loop. The first option is a timed purge valve that allows the separator to "blow down" the contained solids. This is the preferred option for customers who want to reduce maintenance activities, and prefer an automated filtration solution. This is how the separator in Figure #1 is configured.

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The second option is a separator configured with a solids recovery vessel (SRV) that collects the solids in a chamber. The vessel contains a bag filter that is removable, and requires maintenance personnel to empty it as it fills up. This accessory allows the user to see what kind of particulate is being removed by the separator, and it also reduces the amount of water loss during solids removal, compared to the purge valve. Figure #2 shows a separator configured with a solids recovery vessel.

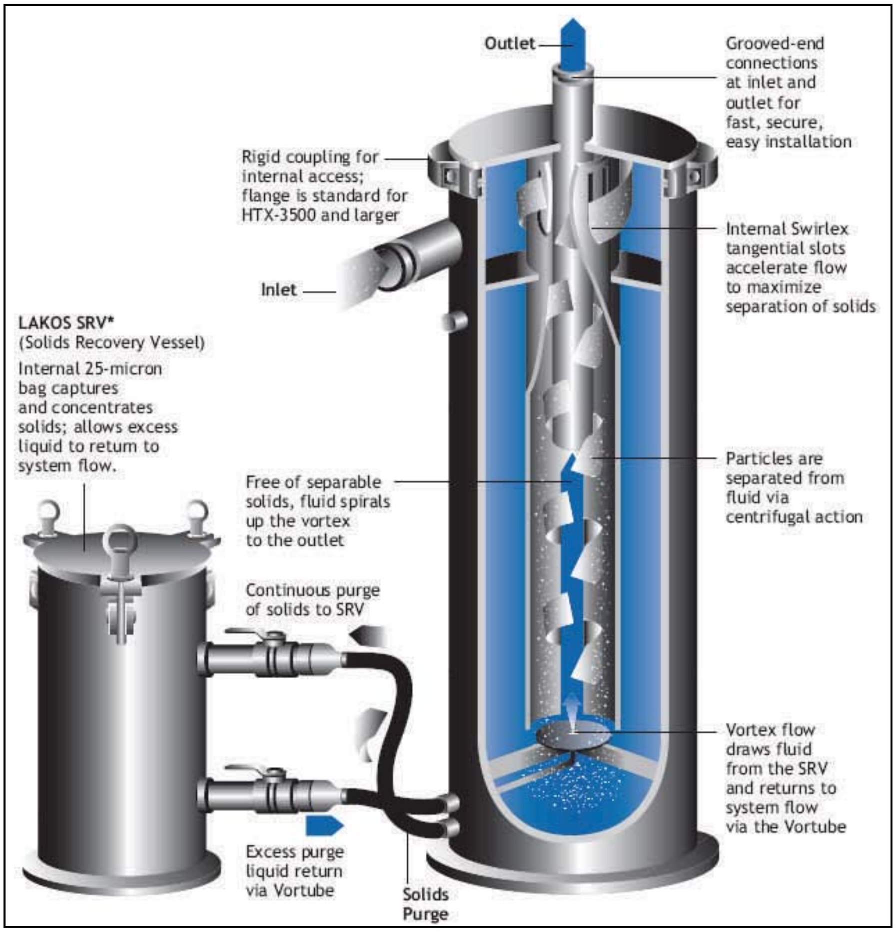

Figure #2—Separator with Solids Recovery Vessel

Perhaps the most beneficial characteristics of the separator are its reliability and low cost of ownership. The Lakos separator has no moving parts inside of it that can wear out and require replacement. There are no filtration media elements that must be monitored and regularly replaced. Because of this, there are no on-going operational or maintenance costs associated with the separator, which translates into the lowest cost of ownership in comparison to other filtration options.

Conclusion:

Because cooling towers introduce so much airborne particulate into the water loop, and because of the reality of corrosion induced deposits, filtration should be included on all cooling tower system loops The benefits to filtration include increased heat transfer efficiency and reduced risk of under-deposit corrosion.

Furthermore, selection of a separator system to address filtration results in the least amount of on-going maintenance effort, excellent filtration efficiency, and the lowest cost of ownership ~

References:

- *Corrosion Information Reference:* **Corrview International** www.corrview.com *CorrView manufactures corrosion monitors and provides solutions to HVAC and plant operational problems*
- ***Carrier** Design Manual—Part 5*
- *Cooling System Filtration: Accessory or Necessity?* AFE Facilities Engineering Paper, Michael McDonald