

**EFFECTIVELY CLEANING CELLULAR PLASTIC COOLING TOWER FILL**

**PRESENTED AT:**

**THE 33<sup>rd</sup> ANNUAL ELECTRIC UTILITY CHEMISTRY WORKSHOP  
AT THE UNIVERSITY OF ILLINOIS**

**JUNE 11–13, 2013  
HAWTHORN SUITES BY WYNDHAM  
CHAMPAIGN, ILLINOIS**

Presented by:

Raymond M. Post, P.E.  
Director, Cooling Water Technologies  
ChemTreat, Inc  
5640 Cox Road  
Glenn Allen, VA 23060  
804-627-2369  
RayP@chemtreat.com

Co-authors:

Kevin Emery  
Senior Technical Consultant  
ChemTreat, Inc.

Gene Dombrowski  
Account Manager  
ChemTreat, Inc.

Michael Fagan  
Manager, Technology and Applications  
US Peroxide

## **Abstract**

The transition from splash fill and ACB fill to cellular plastic “high efficiency” film fill in cooling towers has reduced capital and operating costs. However, the generally tight and tortuous path that provides exceptional contact between air and water in these fills also makes them highly prone to fouling. In the US Power industry, environmental regulations limiting chlorine usage, inadequate or non-existent clarification and filtration equipment, and generally lower treatment levels exacerbate the difficulty of controlling deposit formation in the fill packs. Fouled fill sacrifices the “high efficiency” performance gains and, in advanced stages, results in fill collapse into the sump and expensive fill replacement. The purpose of this paper is to outline and review successful, pro-active fill cleaning techniques that preserve thermal efficiency and avoid fill replacement. Several case histories are provided.

### Keywords:

Cellular plastic fill, film fill, high efficiency fill, cooling tower, cleaning

## Introduction

Cooling tower performance is highly dependent on the efficiency of contact between the hot water and cool air. The efficiency of air-water contact can be maximized by using corrugated PVC sheets stacked together sometimes less than 0.5" on center.

The industry transition from less efficient, but more open splash fill and ACB fill to "high efficiency" cellular plastic fill packs has reduced capital and operating costs and boosted cooling performance in retrofit applications. However, the generally tight and tortuous path that provides such exceptional contact between air and water also makes these fills highly prone to fouling. In the US Power industry, environmental regulations limiting chlorine usage, historic absence of clarification and filtration equipment, and generally lower treatment levels exacerbate the difficulty of controlling deposit formation in the fill packs. Fouled fill sacrifices the performance gains, and then some. In advanced stages, fouling results in a ~10x weight gain, leading to fill collapse into the sump and expensive fill replacement. This paper outlines and reviews successful, pro-active fill cleaning techniques that preserve thermal efficiency and avoid fill replacement.

## Background

Power plants in the US were historically designed with cooling towers using either splash fill or asbestos cement board (ACB) film fill. As shown in the photos below, both splash and ACB types are relatively open configurations that are essentially immune to fouling. It has been observed that a moderate amount of fouling improves surface roughness and slightly increases both wettability and surface area for evaporation.



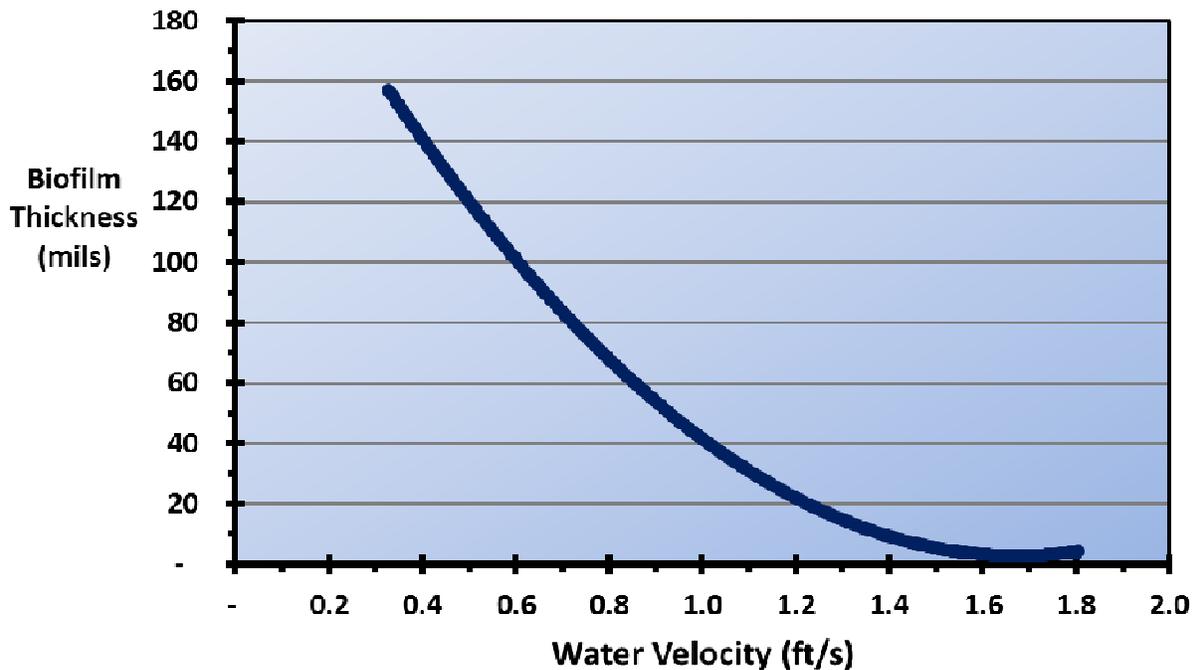
**Figure 1. Splash Fill**



**Figure 2. Asbestos Cement Board (ACB) fill**

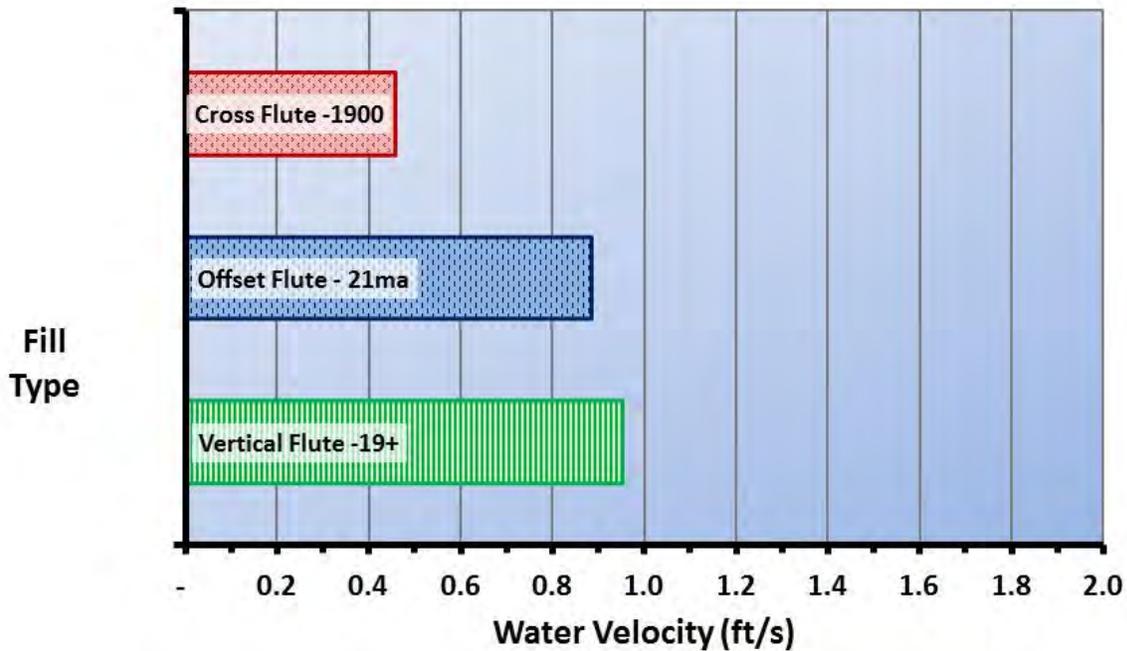
In US power plants, the most critical heat exchanger, the condenser, was historically designed with smooth bore copper alloy tubes that are naturally resistant to biofouling. Moreover, to promote heat transfer, condensers are designed with comparatively high water velocities in the range of 6-7 ft/s, which also prevents suspended solids deposition and further reduces the tendency for biofouling adhesion, as shown in Figure 3.<sup>2</sup> In reasonable consideration of these prevalent system characteristics, US power plants

historically were designed with minimal solids removal equipment (clarifiers or filters) on the makeup water and rarely included sidestream filtration to remove particulate matter such as road dust or flyash that often entered the cooling tower with the air. Also in reasonable consideration of these design factors, Burns and Roe, the USEPA contractor responsible for developing the technology based effluent limitation guidelines for power plants, recommended no more than 0.2 ppm free available chlorine average residual for 2 hours per day as “Best Available Technology”.<sup>1</sup> While that may have been the “best available” technology for the power plants of the day, it is conceivably the “worst imaginable” technology recommendation for a modern power plant with high efficiency cellular plastic film packs and stainless steel or titanium condenser tubes.



**Figure 3. Biofilm thickness as a function of water velocity<sup>2</sup>**

A comparison of the typical water velocity in cooling tower fill shown in Figure 4 with the biofilm thickness shown in Figure 3 highlights the vulnerability of cellular plastic film packs to biofouling. The water film velocity in typical cross-fluted film packs has been reported to be only 0.48 ft/s, and for fouling resistant film packs, only 0.89 ft/s - 0.95 ft/s for an 8 gpm/ft<sup>2</sup> water loading rate.<sup>3</sup>



**Figure 4. Water film velocity for typical cellular plastic fill packs of cross-fluted and fouling resistant designs.<sup>3</sup>**

Relatively speaking, a heat exchanger with a water velocity < 1 ft/s would be considered a severe fouling risk. The high volumes of water used by power plant cooling systems make it impractical or uneconomical to employ the higher levels of dispersants commonly used for cooling towers in other industries.

Constrained by environmental regulations, plant configurations, and economics, the power industry has suffered disproportionately from cooling tower fill fouling. Moreover, the power plant cooling water community has been slow to develop the awareness that the cellular plastic fill pack, not the condenser, is generally the most critical component with respect to deposit control in today's cooling tower circuit. The choice of cellular plastic fill encourages the abandonment of some older practices, such as the injection of sawdust or horse bedding to stop condenser tube leaks, and the implementation of better practices with respect to clarification, filtration, microbiological control, and scale inhibition.

### **Options for dealing with fouled fill**

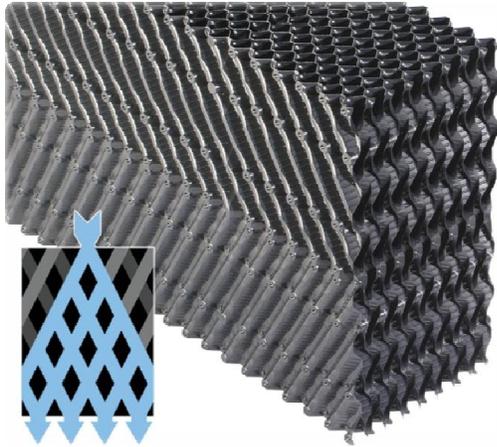
Many utilities have suffered from fouled cellular plastic fill. Several have opted to replace the fill in kind, while others have chosen low fouling fill designs that generally feature a more vertical flow pattern, less surface texturing, and sometimes wider spacing between the plates, all at the expense of some cooling efficiency. Since fill replacement can be expensive in terms of both materials and outage time, others have chosen to clean the fill chemically, or sometimes, mechanically. The choice of replacement vs. cleaning, as well as the cleaning methodology, requires careful consideration. The decision depends on the extent of the fouling, the physical and chemical nature of the

foulant, the type of fill, and environmental considerations in dealing with cooling tower blowdown. For example, in heavily fouled film packs, some passages may be completely blocked, preventing the cleaning solution from flowing through, and perhaps act as a filter for solids removed in other parts of the pack. The total mass of deposits, if released at once into the recirculating water flow will result in very high suspended solids, and blowdown flow may have to be diverted or treated prior to discharge. The nature of the foulant also varies considerably depending on the nature of the circulating water and the treatment chemistry employed. The cooling tower fill is the most fouling prone area of the cooling system and will find the weakest link in the deposit control program. In smaller process cooling towers where acid feed is undesirable or prohibited, calcium carbonate scale predominates. Power plants in some countries are also prohibited from using acid, and suffer from calcium carbonate scaling in the fill. In the US, power plants typically feed acid and the appropriate scale inhibitors when needed, and are more likely to foul from a matrix of biofouling and suspended solids. This tendency is due to a general absence of clarification and filtration equipment and efforts to comply with chlorine discharge regulations without resorting to dechlorination. Table 3 summarizes a survey of cooling tower fill foulants from power plant cooling towers at several US locations.

Foulant	FL Silica	IA Silt & coal dust	SC Kaolin	WA Bentonite & CaCO <sub>3</sub>	NY CaCO <sub>3</sub> & Silica	LA Iron & Organics	FL Silt and Clay	GA Kaolin
LOI	25	34	18	17	24	26	16	11
Al <sub>2</sub> O <sub>3</sub>	13	2	12	10	6	0	17	19
MgO	0	3	11	7	1	0	0.5	2
SiO <sub>2</sub>	47	24	47	58	12	5	38	54
CaO	2	9	3	3	25	10	7	0
Fe <sub>2</sub> O <sub>3</sub>	6	14	8	5	3	41	0	11
MnO <sub>2</sub>	3	10	1	0	0.5	7	0	0

**Table 1. Tower fill inorganic deposit analyses from several US locations<sup>4</sup>**

The generally high loss on ignition is evidence of a significant microbiological component, which acts as a binder for suspended solids. Over time, the fouling matrix behaves as a filter media, trapping additional suspended solids particles in the crevices of the fill pack and impeding air and water flow. At this point, the efficiency gain that was the driving force for selecting the fill, has been sacrificed.

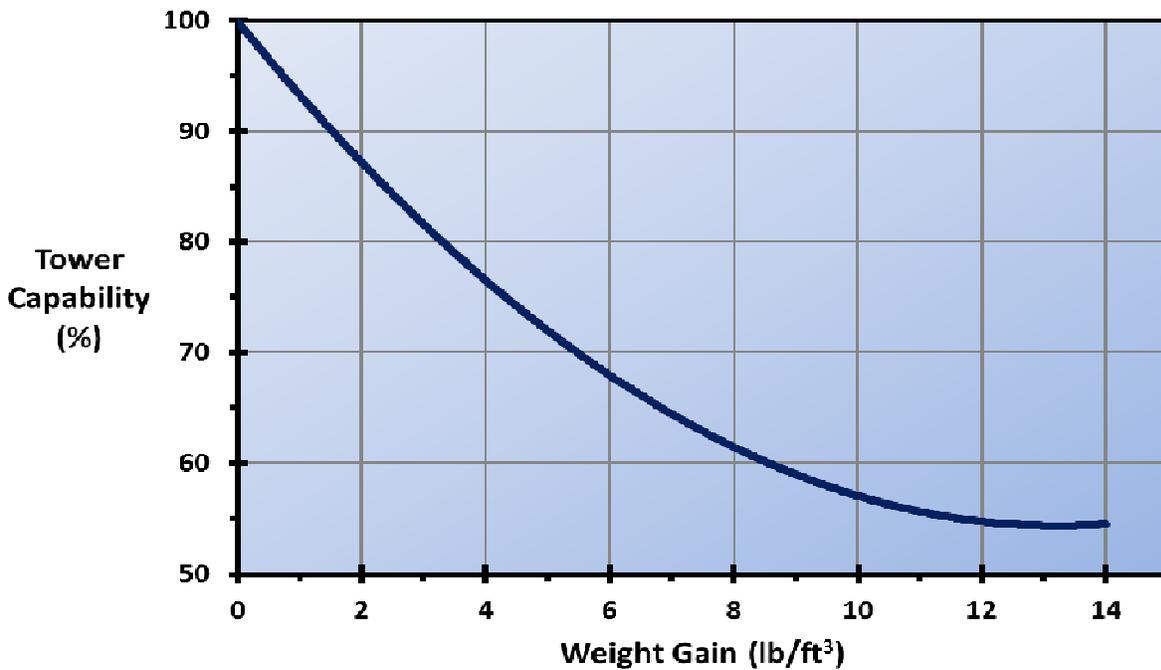


**Figure 5. High efficiency cross-fluted fill (Brentwood Industries)**



**Figure 6. Fouled cross-fluted fill that is no longer highly efficient**

The loss in cooling tower capability as a function of fill weight gain for a fill pack with offset flute design is trended in Figure 5.<sup>5</sup>



**Figure 7. Tower capability loss vs. fill weight gain for a standard offset flute cellular plastic fill pack.<sup>5</sup>**

Over time the high efficiency fill becomes increasingly less efficient, gains as much as 10x its initial weight, begins to extrude around the supporting beams, and ultimately collapses into the sump. At the point where performance loss becomes very obvious to operators or the fill begins to deform, it is too late to consider cleaning as an option; fill

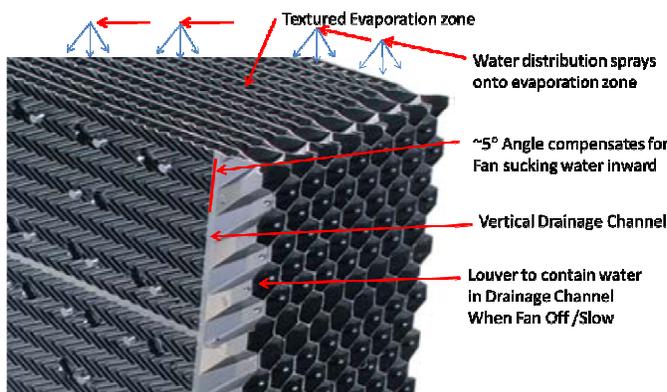
replacement is required. However, if the fouling is detected in its early and moderate stages, several cleaning options are available for consideration, depending on the nature of the foulant. A slow rate of buildup on high efficiency fill is almost inevitable on cross-fluted fill packs, especially on unclarified water. In such cases an annual preventative maintenance cleaning may be warranted to prevent the fill from ever reaching a severely fouled condition that would require replacement.

### Cleaning Options for Cellular Plastic Fill

The most appropriate method for cleaning tower fill depends on several factors, including safety concerns, the system metallurgy, in-service vs. out-of-service cleaning, potential impact on plant operations, disposal options for the cleaning solution, impact on the environment, and the chemical and physical nature of the foulant. Appropriate cleaning methods for the most common foulants will be discussed along with their strengths and limitations, with emphasis on the microbiological-silt matrix prevalent in US power plants.

### Cleaning Mineral Scales

Hard mineral deposits found in cooling tower fill most commonly consist of silica or calcium carbonate. Silica solubility is lowest at low temperature, and silica deposits often occur near the bottom of the counterflow fill pack where the temperature is lowest, the water is most concentrated, and uneven water/air distribution can lead to dry spots or locally concentrated areas. Calcium carbonate deposits often occur throughout the fill pack, but are generally heaviest toward the bottom. Higher temperature near the top of the fill pack has the lowest calcite solubility and promotes faster deposition kinetics. However, as the water passes through the fill, the minerals are concentrated slightly by evaporation and the pH will rise slightly as excess  $\text{CO}_2$  is stripped and  $K_w$  shifts due to lower temperature. Hard mineral scales are also prevalent at the edges of the cross-flow film packs with integral louvers that are commonly used in smaller packaged cooling towers as shown in Figures 8 and 9.



**Figure 8. Cross flow film pack with integral louver showing louver**



**Figure 9. Scaled wet-dry interface area of integral louver fill**

One technique that can be used effectively on either hard scale in its early stages is to apply certain types of surfactants that are capable of penetrating the hard deposit and

encouraging it to spall from the slightly flexible plastic substrate and disperse with the water treatment program. The surfactant is typically applied in addition to the normal scale inhibitor program for an extended period of 60-180 days. This program is never 100% effective, but will often result in removal of 70-80% of the fouling minerals. Prior to implementing the cleaning process, it is imperative to identify and correct the scaling condition. This program has the advantages of being able to be used on cooling towers of galvanized construction, low environmental impact, and negligible safety risk. It is an excellent low cost, low risk option to evaluate prior to more extreme cleaning processes. On very small cooling towers with integral louvers, the surfactant is effective when used off line by spraying a 5:1 dilution on the fill and rinsing with a low impact pressure washer so as not to damage the film fill. Before and after photos of the surfactant cleaning process applied to a cross flow external louver fill pack are shown in Figures 10 and 11.



**Figure 10. Fouled cross-flow, external louver high efficiency fill pack**



**Figure 11. Same fill pack after 124 days specific surfactant treatment**

For large cooling systems where the predominant foulant or is calcium carbonate, the fill can be cleaned by reducing the operating pH and/or cycles of concentration to the point where the water is undersaturated with respect to calcite at the fill conditions. Calcite often serves as the binder for the deposit matrix, so dissolving the calcium carbonate in the deposit matrix can be disproportionately effective. In principle, any degree of undersaturation will be effective over time. The old test for calcium carbonate solubility was to place a carefully weighted calcite marble in solution and measure whether it gained or lost weight over time. In practice, the further below saturation the solution is, the faster the scale will dissolve. pH values ranging from about 3 to 6 have been used successfully, with the lower pH obviously being much faster, but posing greater risk to metallurgy and the environment. In principle any acid that will achieve the desired pH at reasonable cost, and with an appropriately soluble calcium salt, can be used for this process. Sulfuric acid is an obvious choice for many plants that already use it for pH control. Other plants may prefer to use safer, less corrosive acids such as organic acids or inhibited sulfamic acid.<sup>6</sup> It has been observed that some organic acids are more effective than mineral acids at intermediate pH's and synergistic with sulfuric acid. At pH 5, application of the appropriate organic acid will accelerate the rate of calcite

dissolution by 10-20x relative to sulfuric acid alone. Photos illustrating the effectiveness of the organic acid-sulfuric acid chemistry in cleaning a coil-shed tower are shown in Figures 12-15.



**Figure 12. “Coil shed” tube bundle showing tube OD’s encased in a thick layer of white calcium carbonate at the start of the cleaning**



**Figure 13. Tube bundle totally white with calcium carbonate under a spray nozzle near the start of the cleaning procedure**



**Figure 14. Tube bundle showing some bare tube metal part way through the cleaning procedure.**



**Figure 15. Tube bundle at the completion of the cleaning process showing mostly bare tubes.**

For predominantly light calcium carbonate scaling, off-line foam acid cleaning has been practiced very successfully, at least on smaller towers. Strong acid foam is applied by skilled specialists from the top of the fill pack. The nature of the foam allows the acid to contact the scale as it slowly passes downward through the fill. The relatively low volume of spent and mostly neutralized foam cleaning solution is either accumulated in the sump and disposed of, or allowed to mix with other circulating water from neighboring tower cells that may in service, depending on plant safety and environmental requirements.

### ***In Situ* Mechanical Cleaning of Hard Scales from Fill Packs**

Mineral scales and also be mechanically cleaned with some success in situ or ex-situ. Due to its brittle nature relative to the flexible PVC, the scale can be dislodged with some success by mechanically cleaning the fill pack *in-situ* from below. Figure 16

illustrates such a purpose-built cleaning device being used to remove calcium carbonate scale on a large natural draft cooling tower, with cleaning jets that can be inserted part way into the fill pack. Power plant mechanical draft cooling towers can generally be cleaned from both sides with a reach of only 25 feet. For cleaning predominantly silica scale, which tends to accumulate at the bottom of the fill pack, at least one utility has used a simple pipe and water nozzle arrangement affixed to a forklift. The nozzle assembly is lifted to within 2-3 feet of the bottom of the fill pack and the fork truck is maneuvered around the outside of the tower basin to progressively jet the bottom of the entire fill pack.



**Figure 16. Mechanical cleaning apparatus for calcite scale on a natural draft tower.**

### ***Ex Situ* Mechanical Cleaning Of Hard Mineral Scales**

In many cases, the scaling has progressed to the point where in-situ cleaning is no longer feasible. For calcium carbonate scales, chemical dissolution may still be a viable option in such circumstances. However, hard silica or calcium sulfate scales are much more difficult to clean chemically. In such cases the only viable option may be to physically remove the fill packs from the tower and mechanically clean and replace the packs. Depending on the age and type of fill, it may have become too brittle to remove from the tower and mechanically clean without very significant breakage. However, ex-situ mechanical cleaning is still a viable option in some cases, depending partly on local labor costs. Figures 17 and 18 illustrate a successful mechanical cleaning of cooling tower fill packs that were heavily fouled by hard silica scale.



**Figure 17. Forehand mechanical cleaning technique for silica scales.**



**Figure 18. Cleaned fill section. Note minor mechanical damage and pile of removed deposit.**

### **On-Line Slow Cleanup of Lightly Fouled High Efficiency Fill**

As noted earlier, when fouling is identified in its early stages, it is possible to arrest or even reverse the fouling by correcting the deficient conditions and applying the appropriate deposit control chemistry, without resorting to extreme measures. In one such instance, a cross-fluted fill pack tower fill was determined to be fouled with a calcium carbonate-silt matrix. The first 1'x2'x6' fill pack under the sprays was clean, but the diligent inspection team worked down into the second layer of fill. Five 1'x2'x6' fill sections taken from the second layer were examined and weighed. The average weight in the damp-dry condition was 78 lb. as compared to a new dry weight of 31.2 pounds per section. This equates to a 3.9 lb/ft<sup>3</sup> weight gain, which would be light to moderate on the scale shown in Figure 7. Despite the calcium carbonate content, the deposit consistency was soft and mud like. The tower manufacturer suggested replacing the cross-fluted fill with their clog resistant design at considerable expense. The root causes of the fouling were identified to be excessive clarifier carryover, another significant source of mud ingress that went undetected and weak practices relating to adjusting scale inhibitor dosage relative to pH variations. Figures 19 and 20 show the condition of the second fill layer and the top of the third layer.



**Figure 19. Bottom of 2<sup>nd</sup> layer of fill**

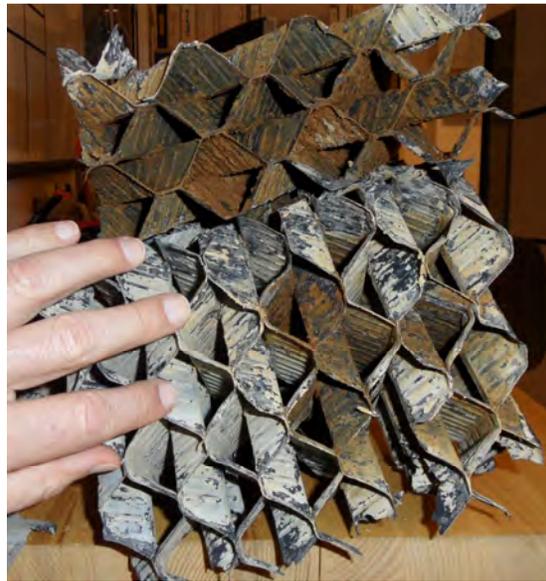


**Figure 20. 2<sup>nd</sup> layer and top of 3<sup>rd</sup> layer**

Following the outage, all program deficiencies were promptly corrected. At the next brief outage 7 months later, the tower fill was re-inspected in the same area and a smaller piece was removed for closer examination. A section of fill was re-weighed at 35-36 lb., or only 3.0 lb./ft<sup>3</sup>, only 0.9 lb./ft. more than the as-new dry condition. During the 7-month period the fill actually lost 43 lb./section, presumably due to correcting the fouling conditions, applying an effective dispersant program, and the gentle action of hot water washing over a soft deposit. Photos of the previously fouled section that was removed for inspection are shown in Figures 21 and 22 below. The surface texturing on the original fill surface is clearly visible in the photos.



**Figure 21. Close up of cross-fluted fill 7 months after restoring proper treatment**



**Figure 22. Close up from end view showing open passages and fill texture**

### Cleaning Microbiological – Organic – Silt Deposit Matrices

The combination of suspended solids with microbiological growth is well known by tower fill manufacturers to represent a more severe fouling potential. Manufacturer fill selection guidelines generally include guidance for a higher level of suspended solids with good microbiological control, and a much lower allowable suspended solids limit for poor biological control, as shown in Table 2.

	19 mm Cross Flute	21 mm Offset Flute	19 mm Vertical Flute
TSS (ppm) with good MB control	<100	<200	<500
TSS (ppm) with poor MB control	<25	<50	<200

**Table 2. Guidelines for Tower Fill Selection (Brentwood Industries)**

Deposits where microbiological growth or organics serve as the binder for the deposit matrix are characterized by a soft, sometimes putty-like consistency. Unlike mineral scales, deposits of primarily microbiological origin tend to accumulate primarily in the middle of the fill pack. Water velocities directly under the spray nozzles are generally high enough to discourage microbiological adhesion. For this reason, microbiologically initiated fouling sometimes goes undetected because it is not visible on inspections from the top looking down beneath the spray headers. As the water velocity slows down several inches into the fill, microorganisms begin to colonize the surface, acting as a filter for suspended solids passing through the fill. In an advanced stage, fouling tends to be most intense in the middle of the fill than at the bottom because suspended solids are filtered out prior to reaching the bottom layer, and because the last few inches of fill do not physically support a thick, soft deposit mass. The inability to clearly view microbiologically initiated fouling from either top or bottom, combined with the difficulty of inspecting the middle layers of fill, often allow this type of fouling to progress undetected until it has reached an advanced stage. Power plants and industrial facilities have attempted to monitor fill fouling during tower operation using sections of fill suspended from load cells, or by cutting an access window into the end of the tower casing to allow a middle section to be removed periodically for inspection using a man lift, or by suspending a section of fill beneath the main fill pack to allow it to be easily inspected and weighed. All of the methods can work, but none have proven to be totally satisfactory.

There are several effective methods to remove biological-silt matrix deposits from cooling tower fill. Hyperhalogenation is a widely attempted method, but the effectiveness is usually disappointing and corrosion to system components and the need to dechlorinate prior to discharge are important considerations. Microbiological matrices often have high water content and will shrink and detach from surfaces when thoroughly dried. US Patent 5,558,157 claims a similar method for biofilm removal in shell and tube heat exchangers.<sup>7</sup> However, effectively drying out cooling tower fill can prove problematic even with the help of fans even if the tower is located in a low

humidity climate. Chlorine dioxide has also been used as a cleaner for cooling tower biofilms with some success. However the most widely practiced and effective cleaning method for deposits having microbiological or organic binders is hydrogen peroxide. Hydrogen peroxide is effective due to its oxidizing strength and as a result of the physical action of the oxygen micro-bubbles produced as it reacts with organic deposits. The positive environmental profile of hydrogen peroxide involving rapid breakdown to water and oxygen, and ease of application are additional factors favoring peroxide as a tower fill cleaner. Typical dosages are in the range of 500-3,000 ppm active hydrogen peroxide. As with most cleaning operations, the addition of low levels of surfactants will help loosen deposits. Polymeric dispersants are generally added to assist in keeping the removed solids in suspension until they can be blown down and preventing solids redeposition.

The before and after cleaning photographs in Figures 23-28 visually illustrate the capability of peroxide to remove microbiological fouling from cellular plastic fill packs. In this case, the microbiological fouling was the result of an organic process leak at a chemical plant. Soluble organic carbon is the limiting growth nutrient in industrial cooling waters, and any increase can lead to explosive log growth and very severe fouling, despite the robust chlorine-bromine-non-oxidizing antimicrobial program in place at this facility. The tower is equipped with a sidestream filter which was key in minimizing fouling buildup and averting a more serious situation.



**Figure 23. Tower fill pack from bottom prior to peroxide cleaning.**



**Figure 24. Tower pack after peroxide cleaning.**



**Figure 25. Close-up of underside of fill pack prior to peroxide cleaning showing goeey slime buildup.**



**Figure 26. Close-up of underside of fill after peroxide cleaning showing biofouling substantially removed.**



**Figure 27. Structural supports prior to peroxide cleaning showing some green algae buildup.**

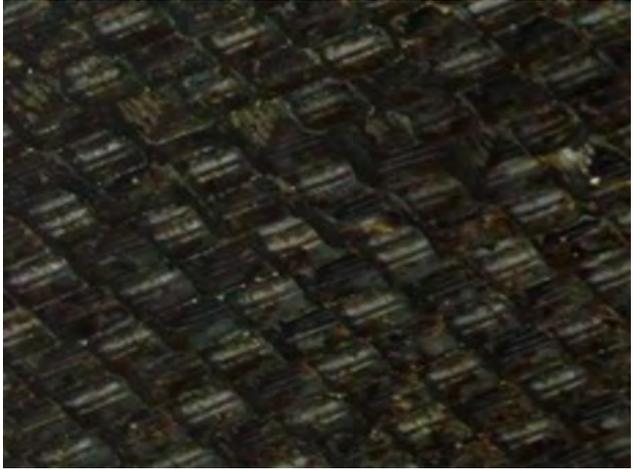


**Figure 28. Structural supports after peroxide cleaning showing algae substantially bleached and removed.**

Much of the biomass is extracellular and intracellular water and organics that will dissolve with peroxide cleaning. However, many power plants lack makeup water clarification and filtration equipment and a substantial portion of the deposit consists of inorganic mud and silt that will be released into the water. In cases where the deposit contains a high percentage of inorganics, the circulating water can be expected to become highly turbid. Figures 29 and 30 illustrate the appearance of a slime-clay matrix on moderately fouled high efficiency cooling tower fill before and after cleaning. Figures 31 and 32 illustrate the corresponding appearance of the cooling tower basin during cleaning. Figures 32 and 33 show the appearance of a crossflow tower sump prior to, during, and after cleaning and flushing. The potential for high suspended solids in the cooling tower blowdown should be anticipated when cleaning a severely fouled system and accounted for in the job planning scope.



**Figure 29. Cross-fluted tower fill fouled with a slime-clay matrix prior to peroxide cleaning**



**Figure 30. Cross-fluted tower fill after peroxide cleaning.**



**Figure 31. Counterflow combined cycle power plant tower screen pit during cleaning.**



**Figure 32. Tower basin during cleaning with "sludge judge".**



**Figure 32. Tower sump of heavily fouled industrial cross flow film fill tower prior to peroxide cleaning**



**Figure 33. Tower sump of same cross-flow tower during peroxide cleaning. Peroxide is very effective at dislodging biofilm-silt deposit matrices.**



**Figure 34. Tower sump after flushing**

### **Hydrogen Peroxide Fill Cleaning Case History:**

One of the difficulties in preparing a paper on tower fill cleaning experiences is the difficulty of obtaining hard numerical data. The fill areas of counterflow towers are considered confined spaces and generally cannot be entered when the tower is on line. The tower fill sections of interest are the second or third layer, and these are time consuming to “excavate”, inspect and weigh. On-line fill weight instrumentation and sidestream weight monitoring devices are rare, and the likelihood of capturing the fouling and cleaning cycle is even less likely. We were somewhat fortunate to be involved in a situation where it was possible to observe and collect numerical data on fill weight starting from a conversion from splash fill and progressing through the fouling and cleaning events.

The tower as modified is an 80,000 gpm, counterflow design with 8 ft. of fouling resistant offset flute cellular plastic fill. The monitoring equipment at the time included on-line instrumentation for fill weight, corrosion rate, and heat transfer resistance. The suspended solids removal equipment consists of an upflow filter that receives both unclarified river water and recycled cooling tower water in a sidestream configuration. The robust chemical treatment program consists of chlorine-bromide, periodic non-oxidizing biocide, surfactant, organic phosphate scale inhibitor, polymeric dispersant, and azole for copper corrosion inhibition.

Shortly after restarting the retrofitted tower in early summer, the filtration system began experiencing serious mechanical difficulties, causing high levels of suspended solids in the tower. Tower fill weight instrumentation recorded a steady increase during this period, but the accuracy and reliability of the instrumentation was uncertain. The heat transfer resistance monitor showed no decrease in performance. Cooling tower fill inspection was postponed until the winter months when it would not impact production. Figures 35 and 36 shows the condition of the top 4' layer of fill. Note that no fouling is evident looking down from the nozzles in Figure 35 and that accumulations are light for the first 6-12 inches at the top of the pack beneath the nozzles, where the water velocity is highest.



**Figure 35. Fouling is not readily apparent on cursory inspection looking down from spray nozzles.**



**Figure 36. Fouling is light for the first 6-12 inches down into the fill pack due to higher water velocities at the top.**

A deposit sample was collected for analysis. The amount for free water was 87.2% (weight loss at 105 °C), which is consistent with a high biological content. The ash analysis 650 °C indicated a relatively high LOI consistent with a biological matrix in conjunction with alumino-silicate clay and iron with minor amounts of calcium, magnesium, zinc, and phosphate. The high LOI and moisture content provided confidence that the deposit could be successfully cleaned using peroxide.

<b>LOI @650C</b>	<b>26.5</b>
Silica	41.3
Aluminum, as Al <sub>2</sub> O <sub>3</sub>	15.2
Iron Oxides, as Fe <sub>2</sub> O <sub>3</sub>	7.3
Calcium, as CaO	2.3
Phosphate, as P <sub>2</sub> O <sub>5</sub>	1.6
Zinc, as ZnO	1.2
Magnesium, as MgO	1.0

**Table 3. Fill inorganic deposit analysis**

The cleaning procedure was to shot feed 1,000 ppm active peroxide over a period of approximately 20 minutes. Turbidity and peroxide concentrations were monitored and heavy blowdown was initiated when the turbidity peaked at 420 NTU at approximately 3.5 hours following the start of injection. The peroxide concentration peaked at 800 ppm and declined to 250 ppm after 6 hours and was essentially zero after 15 hours

Figure 37 shows the Fill Weight Trend from the initial fill installation through the fouling buildup and through the peroxide cleaning sequence. As shown in the graph, most of the benefit was derived from the initial cleaning.



Figure 37. On-line fill pack weight measurements from installation through peroxide cleaning. The initial peroxide cleaning removed 150 lb. of deposit weight from the test cell.

Figures 38 and 39 show the condition of the fill pack after the initial peroxide cleaning. Substantially all of the deposit has been removed. Figure 40 shows the cooling tower basin with a cell off-line and a layer of dirt floated to the surface by peroxide micro-bubbles.



**Figure 38. Tower fill section after peroxide cleaning.**



**Figure 39. Tower fill close-up after cleaning showing essentially complete deposit removal.**



**Figure 40. Tower sump with cell off line after cleaning showing some of the dislodged dirt floated to the surface by peroxide micro-bubbles.**

Figure 41 shows the “instantaneous” (linear polarization resistance) mild steel and copper corrosion rate measured during the cleaning process. The mild steel corrosion rate briefly increased to as much as 4.3 mpy before returning to < 1 mpy at 30 hours. The admiralty brass corrosion rate reached 1.7 mpy at its peak before settling down to <0.2 mpy. The increase in corrosion was considered modest given the short duration of the cleaning. Corrosion coupons exposed for 47 days to all three peroxide treatments in the hot return water measured 0.6 mpy for mild steel and 0.1 mpy for admiralty.

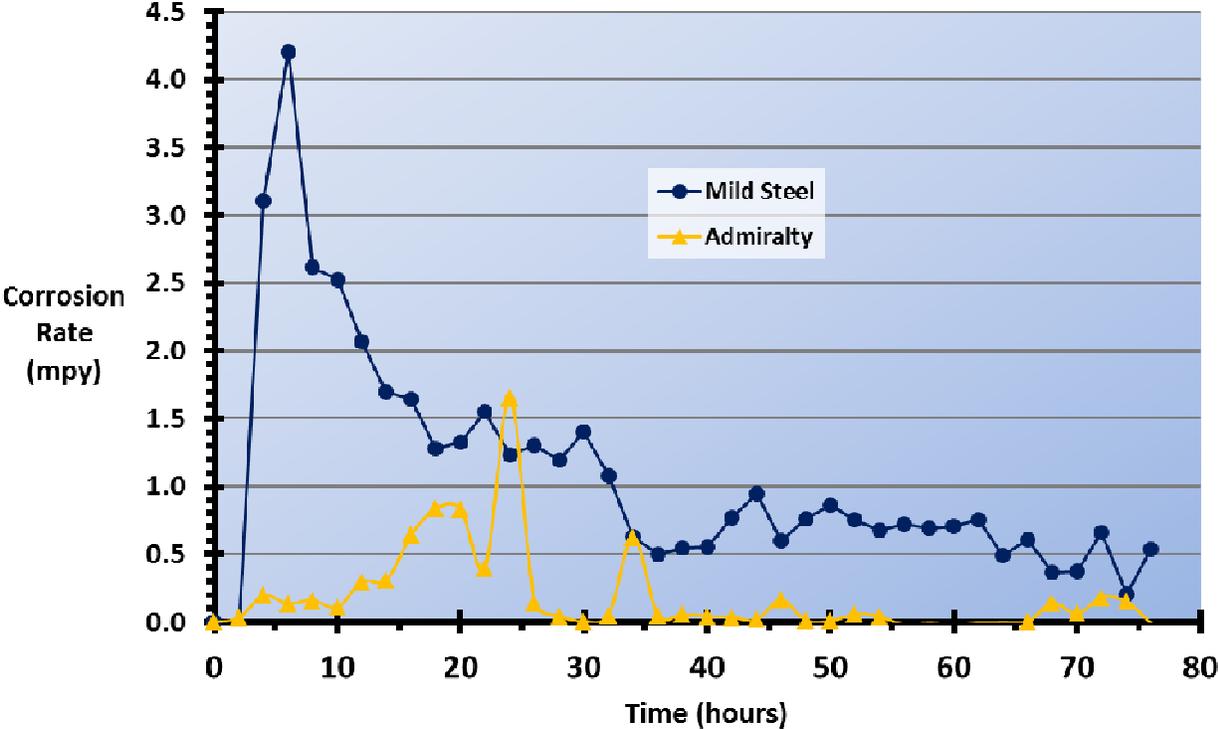


Figure 41. On-line corrosion rate measurements for mild steel and admiralty brass during the first peroxide cleaning procedure. Corrosion rates increased for several hours after the initial shot feed and returned to baseline within 36 hours.

## Conclusions:

- Every effort should be made to prevent deposition from occurring in the first place. Specify a fill type that is compatible with reasonable expectations for the system, considering influent water quality, microbiological control, clarification and filtration equipment, and the possibility for external foulants that might enter the tower through airborne contamination or process fluid leaks.
- Continually review the microbiological and deposit control program to ensure that it is within expectations and delivering the required results.
- Review the performance of any pretreatment and sidestream solids removal equipment to ensure it is delivering and maintaining suspended solids within specifications.
- Be proactive with inspection and monitoring. There are more options, and less expensive ones, if the fouling is detected at an early stage.
- Consider periodic, light, preventative maintenance tower fill cleanings. Most high efficiency fills tend to gain fouling weight slowly over time. Light, annual preventative maintenance cleanings can stabilize or reverse that trend.
- If cleaning is indicated, be sure to adequately address safety and environmental considerations.
- If fouling occurs, consider all remediation options, but generally start with the least costly and least aggressive methods applicable to the nature and quantity of the deposit. Identifying and correcting the fouling conditions at an early stage is least expensive and will be much less expensive than fill replacement if the fouling conditions are allowed to persist.

## References:

- 
- <sup>1</sup> Development document for Effluent Limitation Guidelines and New Source Performance Standards for the Steam Electric Power Point Source Category, EPA 440/1-74 029-a.
  - <sup>2</sup> Characklis, William G., Biofilms, John Wiley & Sons, 1990.
  - <sup>3</sup> Aull, Richard and Post, Raymond, Chemical Treatment Methods and Fill Selection to Minimize Scaling/Fouling in Cooling Towers, EPRI Cooling Technology Seminar, Pensacola, 2012.
  - <sup>4</sup> Hollander, et al., Fouling of Plastic Film Fill, International Water Conference, Pittsburgh, PA., 1993.
  - <sup>5</sup> Monjoie, Michel, Noble, Russell, and Mirsky, Gary R., Research of Fouling Film Fill. Cooling Technology Institute, TP93-06, New Orleans, LA, 1993.
  - <sup>6</sup> Emery, Kevin, Chemical Cleaning Techniques for Galvanized and Stainless Steel Cooling Towers, Cooling Technology Institute, Corpus Christi, TX, 2013.
  - <sup>7</sup> Makowski, et al., Apparatus and Method of Removing Microfouling from the Waterside of a Heat Exchanger. US Patent 5,558,157,1996.