White Paper

Understanding the Environmental Magnitude of
Shell & Tube Heat Exchange Fouling
The Simple Truth.

For organizations taking concrete steps to reduce their carbon footprint, improving chiller performance should be a prime initiative.

Whitepaper provided by Innovas Technologies.

Closing the gap to carbon neutrality by leveraging an alternative solution.

Chiller fouling is a common problem that directly impacts sustainability.

Executive Summary

Shell and Tube Heat Exchangers represent one of the hidden foundations of the global economy. They are used to manufacture fuels, electricity, foods, products, and cooling for both industrial processes and HVAC. These heat exchangers are all around us and if you live in a major city, you are likely closer than a golf shot to an operating shell and tube heat exchanger providing the air conditioning for building cooling. In fact, there are millions of shell and tube heat exchangers in the world and disappointingly, virtually all are operating at less than peak efficiency due to fouling—an accumulation of dirt, slime, or mineral deposits that inhibit the efficient transfer of heat. Heat exchanger fouling is so prolific that it is estimated to cost industrialized countries 0.25% of Gross Domestic Product and is responsible for 2.5% of the total equivalent anthropogenic (man-made) emissions of carbon dioxide (Steinhagen et al., 2011). These are big numbers that equate to the waste of tens of billions of dollars and vast amounts of unnecessary Greenhouse Gas Emissions (GHG) emissions in the U.S. and the world.

Interestingly, the world currently emits roughly 40 Billion man made tons of CO2 into the atmosphere annually. So, as stated by Steinhagen above, 2.5% of man-made CO2 emission caused by heat exchange fouling equals 1 billion tons. That's a lot of unnecessary CO2! For perspective, the world's largest aircraft carrier weighs in at roughly 100,000 tons. That means heat exchangers are emitting the weight of 10,000 aircraft carriers of excess CO2 into the atmosphere every year due to fouling. That's massive energy consumption and GHG emissions that are completely unnecessary and preventable!

Shell and tube heat exchanger fouling is a long-standing problem that translates to both cost inefficiency and excess GHG emissions into the atmosphere. Until recently, the true impacts of fouling have not been adequately defined so the real cost of heat exchanger fouling is not fully appreciated by most owners or operators. More specifically, it is estimated there are more than 300,000 HVAC chillers operating in the US alone and most are handicapped by tube fouling causing tens of millions of tons of preventable GHG exhaust into the atmosphere. For organizations taking concrete steps to reduce their carbon footprint, improving chiller performance should be a prime initiative. These machines represent a great opportunity, ready and waiting, for efficiency enhancement to contribute to a better and cleaner tomorrow.

The Problem with Fouling

All chillers are susceptible to tube fouling. Fouling creates an insulation barrier between the refrigerant and the chilled and condenser water loops, which leads to inefficient heat exchange. Because the entire chiller system is working harder to achieve the cooling demand, more energy input is required to run the refrigerant compressor. This extra power consumption is then responsible for releasing more pollutants into the atmosphere.

There are four types of contamination on heat exchanger tubes, all of which are difficult to remove through manual or chemical cleaning methods. Scaling is when calcium carbonate forms a hard barrier of minerals. Dirt accumulation occurs when dust and silt from outside air are pulled through the cooling tower and deposited on surfaces. Corrosion happens when metallic parts deteriorate and iron oxide forms; it is then eaten by bacteria, causing holes and pits inside the tubing.

But the most problematic form of fouling in a heat exchanger is biofilm. According to a Department of Energy (DOE) fact sheet on cooling towers, "There are two distinct categories of biological activity in the tower system. The first being planktonic, which is bioactivity suspended, or floating in solution. The other is sessile biogrowth, which is the category given to all biological activity, biofilms, or biofouling that stick to a surface in the cooling system" (1).

Bacteria and algae flourish inside chiller tubing because the warm water and biological debris are the perfect breeding ground. The system can even transit bacteria back into the cooling tower once the growth becomes established causing further problems. But the primary challenge with biofilm inside the heat exchanger is that it is up to four times more insulation than scaling leading to that much more energy burn to achieve the same cooling requirements.

Tube fouling can also lead to water waste. "Increased load on the chilled water system not only has an associated increase in electrical consumption, it also increases the load on the evaporative cooling process, which uses more water," according to the DOE's guide on cooling tower management (2). Maximizing the cycles of concentration is a way to reduce makeup water demand but it often leads to increased levels of dissolved solids precipitating onto chiller tubes causing increased inefficiency.

4 Ways Helios Can Green Your Chiller

Helios lowers daily energy consumption with a new way to become more energy efficient.

The traditional way to address tube fouling is through application of chemical water treatment into the condenser and chilled water loops followed by periodic shutdown for manual tube cleaning. To reduce scale buildup, the Department of Energy recommends “using acid treatment such as sulfuric, hydrochloric, or ascorbic acid where appropriate. Acid treatment lowers the pH of the water and is effective in converting a portion of the alkalinity (bicarbonate and carbonate), a primary constituent of scale formation, into more readily soluble forms” (2). Despite the addition of acids into the cooling water, scale accumulation is still common inside operating heat exchangers—leading to energy loss followed by periodic shut down for manually cleaning to reclaim chiller efficiency lost to fouling.

The drawback of chemical water treatment and manual tube cleaning is that they are only partially effective at preventing tube fouling. Chemical water treatment helps with scale management and biofilm buildup, but it does nothing to address particulate matter, and it only reduces tube fouling in heat exchangers, it does not eliminate the problem. As demonstrated in the case study results below, in almost all instances chillers are operating with the use chemical water treatment, yet they are still handicapped 8 to 15% or more due to tube fouling. Additionally, the owner is also required to manually clean the chiller tubes one or more times a year to remove efficiency-robbing buildup. Sadly, once manual tube cleaning is complete and the chiller is returned to service, it immediately begins to foul again and often in a matter of only a few weeks it is just as compromised due to new fouling as it was before manual cleaning. To be clear, water treatment chemicals provide essential benefits for the chilled and condenser water loops, but the only 100% solution to prevent tube fouling in the heat exchanger and truly optimize chiller efficiency is through application of a continuous, mechanical tube cleaning system like Innovas Technologies’ Helios Tube Cleaning System®.

How the Helios Tube Cleaning System® Supports Sustainability
The Helios Tube Cleaning System® ends the issue of tube fouling by injecting small sponge rubber balls into the chiller condenser or evaporator every 20 minutes. As they travel inside the tubing, the balls physically wipe away any residue. This continual cleaning prevents fouling from ever occurring. The entire process is automated, freeing a facility team to attend to other tasks. The Helios Tube Cleaning System® not only protects a chiller’s energy efficiency, but it also delivers four sustainability benefits:

1) Fewer Environmental Impacts
Every kilowatt has an equivalent environment impact. These are commonly measured as reduced emissions, number of trees planted, or cars taken off the road. Our clients typically see an 8 to 15% average gain in chiller energy efficiency, with energy savings up to as much as 25%. Reducing energy consumption puts less pressure on the power grid while also lowering any negative effects the chiller has on our ecosystem.

2) Reduced Emissions for Carbon Neutrality
Many organizations working toward net-zero carbon emissions either add renewable energy or purchase renewable energy credits. But neither approach lowers daily energy consumption. Finding ways to become more energy efficient, such as adopting Helios Tube Cleaning System® technology, concretely moves an organization closer to carbon neutrality.

3) Manual Tube Cleaning is Eliminated
The specialized cleaning balls used in the Helios Tube Cleaning System® are made from specialized sponge rubber. This durable material withstands repeated cleaning cycles. One load of Helios balls lasts for approximately 1,000 hours of chiller operation and are changed quarterly with minimal physical waste. These balls keep the tubes in a chiller continuously clean so that the need for manual cleaning is eliminated. Manual tube cleaning can often require the use of acids or harsh chemicals, high-pressure water and aggressive brushes. After the Helios installation and operation, these items, including the chemicals needed for manual cleaning are eliminated.

4) Enables Greywater Adoption
In many parts of the country, reclaimed wastewater can be used to supply cooling tower makeup water. This can have a major impact on potable water conservation at hospitals and office buildings, where water required for heating and cooling accounts for 20% and 30% respectively of total water use, according to the EPA WaterSense program (3). Because greywater is untreated, however, levels of total dissolved solids and other constituents are highly variable and contribute to very high fouling tendencies in a chiller condenser. Helios Tube Cleaning Systems® enable organizations to more easily deploy greywater for use in cooling towers and chillers without having to worry about increased chiller tube fouling.

Read how four Innovas customers improved their sustainability metrics by adopting Helios.

George Mason University

With an annual energy savings of 550,000 kWh, this retrofit project is estimated to avoid 6,500 tons of greenhouse gas emissions over a 15-year period.

"The benefits include energy cost savings, reduced greenhouse gas emissions, and elimination of workload associated with tube fouling in the Central Heating and Cooling Plant chillers."

George Mason University (Mason) is a public research university in Virginia. Its Fairfax campus resides on 677 acres. Fouling-related chiller inefficiency is a common problem in the D.C. area due to poor water quality. University leadership installed a Helios system on one chiller and ran it side-by-side with an identical chiller without Helios.

Over the course of one cooling season, the results from the comparative chiller performance were striking. The chiller fitted with a Helios Tube Cleaning System® operated with a 0.5°F condenser full-load approach temperature that never changed. The unaltered chiller, however, started the cooling season at a 2°F full-load approach temperature and then climbed higher before topping out above 6°F. The subsequent year, the second chiller was retrofitted with a Helios system and maintained its 2°F condenser approach temperature throughout the cooling season.

The result of these consistent full-load approach temperatures translates to a 10% chiller efficiency gain or up to 200 tons in increased capacity. With an annual energy savings of 550,000 kWh, this retrofit project is estimated to avoid 6,500 tons of greenhouse gas emissions over a 15-year period. That is comparable to:

Eliminating over 1,400 cars

Conserving over 730,000 gallons of gas

Offsetting the electricity consumption of 750 homes

University of Wisconsin-Madison

Reducing 9,200 tons of CO2 emissions over the project's 15-year lifespan.

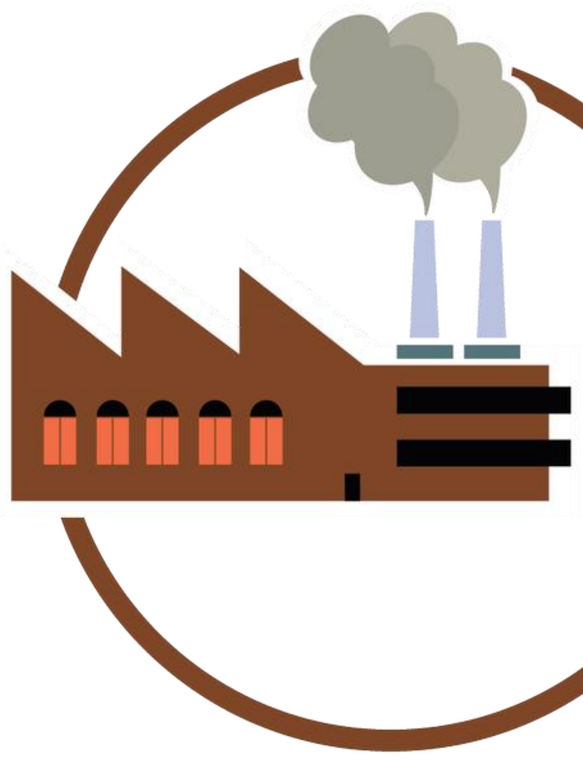
"We have found real value in maintaining clean condenser and evaporator tube continuously…."

Travis Thoeny
Power Plant Manager

Innovas Technologies worked with University of Wisconsin–Madison to analyze historical central utility plant chiller operations data and document chiller efficiency losses due to tube fouling. The analysis found tube fouling-related efficiency loss amounted to approximately 6-8% efficiency degradation. The university then tested a chiller retrofitted with a Helios Tube Cleaning System® and compared it against an identical but unaltered chiller for one cooling season.

The outcomes were game changing. The Helios-enabled chiller experienced a 14% efficiency improvement over the previous year. It also generated up to 400 tons more cooling and consumed less energy than its unaltered twin. This increased chiller productivity is a direct result of Helios keeping the chiller tubes clean and thus optimizing heat transfer efficiency.

The increased chiller capacity and cooling output amounts to 10,370 MMBtu annual energy savings. By reducing 9,200 tons of CO2 emissions over the project's 15-year lifespan, Helios helps this chiller eliminate:



Over 10 million pounds of burned coal

21,300 barrels of oil

22.8 million miles driven by passenger vehicles

Xcel Energy

Plant leadership at a district cooling plant in Denver, Colorado turned to Helios to significantly improve the efficiency of 2,500-ton chiller by managing tube fouling.

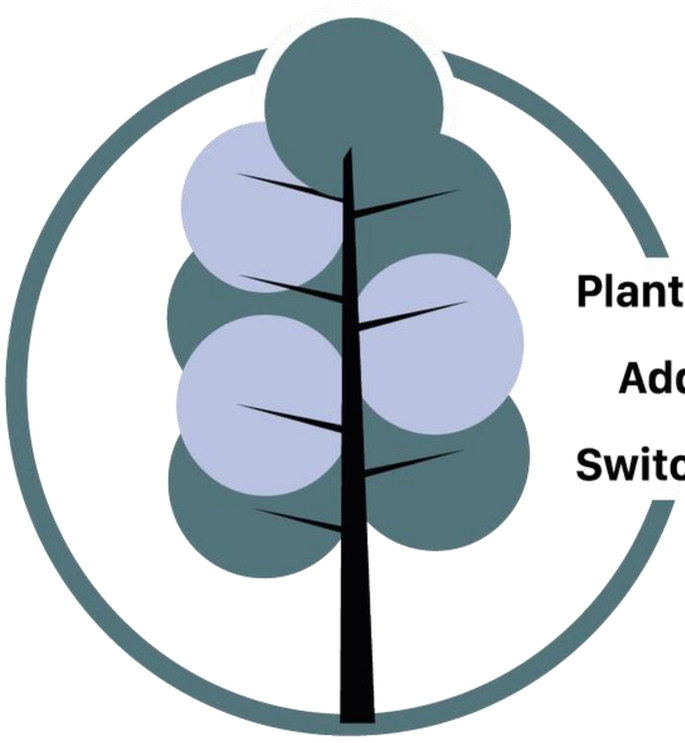
“We used a third party to validate Innovas’ savings numbers and they turned out better than claimed.”

Mike O’Malley
Cooling Plant Manager

Xcel Energy is one of the country’s largest combined electric and natural gas utilities. Plant leadership at a district cooling plant in Denver, Colorado turned to Helios to significantly improve the efficiency of 2,500-ton chiller by managing tube fouling.

By observing chiller operation and performance data from the previous year, the impacts of the Helios system could be accurately documented. The testing period also compared multiple entering condenser water temperatures (ECWT) for additional verification. Chiller efficiency improved by an average of 9% with ECWT of 75F, and improved by 12% with an ECWT of 80 F. Additionally, the chiller cooling output capacity increased due to improved heat transfer, producing as much as 200 tons of additional cooling.

This single chiller upgrade is projected to reduce C02 emissions by 2,220 tons. Sustainability equivalents are comparable to:



Planting over 36,000 trees

Adding close to 3,000 acres of new forest growth

Switching over 83,000 incandescent bulbs to LEDs

Sacred Heart Medical Center

Maintaining approach temperatures within 0.5-2 degrees, virtually eradicating colony-forming bacteria, and eliminating manual cleaning for a four-year period. The Helios upgrade conserves 765,000 kW-hrs annually.

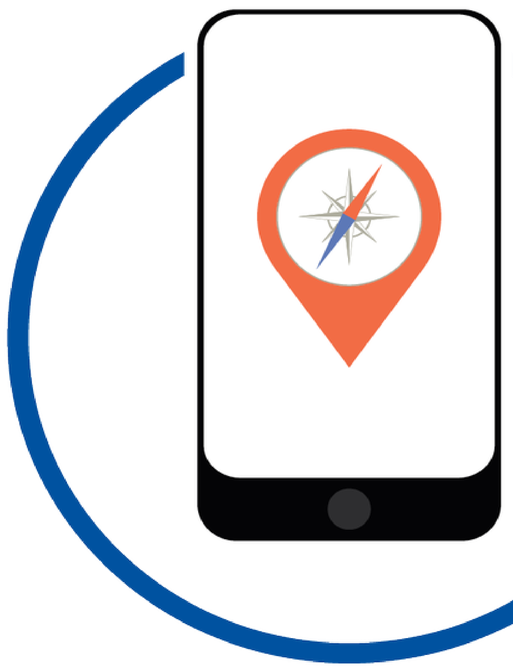
"We couldn't be happier with our ATCS system and its proven results."

Pat Lamb
Central Utility Plant Lead

PeaceHealth Sacred Heart Medical Center at RiverBend in Springfield, Oregon is one of the state's largest hospital complexes. It is built on 160 acres and comprised of more than 1.3 million square feet. With its close proximity to a cherished river system, Sacred Heart was challenged to operate without any chemical-based water treatments for its cooling water operations. But this led to several difficulties.

Though the facilities team employed nonchemical treatment systems and aggressive monitoring, fouling rapidly developed in the condenser loops. This resulted in climbing approach temperatures as high as 17 degrees within only a few weeks after manual cleaning. Shock treatment to manage the persistent biogrowth in the cooling water were also necessary.

Because Automatic Tube Cleaning Systems (ATCS) use no chemicals to keep a chiller clean, it was selected for a trial run. Efficiencies realized include maintaining approach temperatures within 0.5-2 degrees, virtually eradicating colony-forming bacteria, and eliminating manual cleaning for a four-year period. The tube cleaning system upgrade conserves 765,000 kW-hrs annually, which equates to:



Eliminating close to 69 million charged smartphones

Conserving almost 1,300 barrels of oil

Removing about 120 cars from the road

References

1. Steinhagen, H.M, Malayeri, M.R, Watkison, A.P, 2011, Heat exchanger fouling: mitigation and cleaning strategies, Heat Transfer Engineering, Vol. 32, no. 3I4, pp. 189-196

2. Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water Efficiency, *U.S. Department of Energy:* https://www.energy.gov/sites/prod/files/2013/10/f3/waterfs_coolingtowers.pdf

3. Best Management Practice #10: Cooling Tower Management, *U.S. Department of Energy:* https://www.energy.gov/eere/femp/best-management-practice-10-cooling-tower-management

4. WaterSense Best Management Practices, *U.S. Environmental Protection Agency:* https://www.epa.gov/watersense/best-management-practices

* All sustainability equivalents calculated in the case studies using the EPA Greenhouse Gas Equivalencies Calculator

Understand the Environmental Magnitude *of*
Shell & Tube Heat Exchange Fouling
The Simple Truth.

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