Keeping cool

Rainer Haug, Javier Martinez, and Pere Izquierdo, Kurita Europe, examine a new technique for combatting biofouling in downstream cooling systems.

The cleaning of cooling systems is usually quite a complex and complicated task. It requires a shutdown of the related production line or even the whole plant, which leads to enormous production losses and costs.

To keep the system shutdown as short as possible, the cleaning process has to be well prepared and coordinated. It requires experts and specific equipment on site. These do not only cost additional money but are also quite a threat to safety, health, environment and quality (SHEQ). While cleaning the different parts of the plant, it also important to ensure that all construction, dismantling, and cleaning actions are carried out safely. Besides, during these processes, various types of hazardous cleaning chemicals are used, which also need to be reviewed and approved from a SHEQ standpoint.

During a cleaning process, specific parts of a system are dismantled and cleaned one after the other. This is typically done either with a hydro jet or specialised chemical cleaning solutions. Unfortunately, in most cases, these cleaning methods will not only remove the deposits from the surfaces but also the desired corrosion protective layers. These cleaning procedures also generate a large number of different waste solutions which need to be disposed of properly. As such, these complicated procedures can cause additional workloads, which can be costly and reduce plant efficiency.

The cooling labyrinth

In a cooling system, there are a lot of different types of materials used. Starting from different kinds of metals and alloys as piping or for heat exchangers, but also including materials such as concrete in the cooling tower basin or delicate plastic parts as the cooling tower filling material.

The filling material of a cooling tower ensures the easy exchange of the heat to be removed from the cooling water through evaporation. As the capacity of heat exchange through evaporation is a direct function of the available surface, the cooling tower filling materials are engineered to offer the largest possible surface on an as small as possible volume. Therefore, these cooling tower fillings have large but difficult to reach inner surfaces.

On the top of a cooling tower, the warm water is distributed through a spraying system onto the filling packages. Here, the water enters a kind of labyrinth starting at the top, and the only exit is the basin at the bottom. The water itself flows down by gravity as a relatively thin layer on the large surface of the filling. In addition, the filling construction is made in a way to allow the cooling water long contact time with the air, resulting in slow flow velocities of the water on its way down to the basin.

Counterflowing to the water, on its way through the labyrinth, is the air. The airstream ensures partial evaporation of the cooling water, which results in the actual cooling effect. As the heat exchange itself is achieved by partial evaporation of the warm cooling water into the air stream, the evaporation also leads to a concentrating effect of the minerals and salts in the cooling water.

Fresh water that is used to keep the concentration effect in a reasonable balance is called makeup water. The relation of the balance between the amount of evaporated water and the makeup water is generally expressed as cycles of concentration (CoC) and can be calculated according to the following formula. The higher the absolute number of the CoC is, the higher the salt concentration in the cooling water in relation to the make-up water concentration is:

$$coc = \frac{Make\ up\ [\frac{m^3}{h}]}{Make\ up\left[\frac{m^3}{h}\right] - Evaporation\ [\frac{m^3}{h}]} \qquad (1)$$

Figure 1. Basic principle of FReE technology.

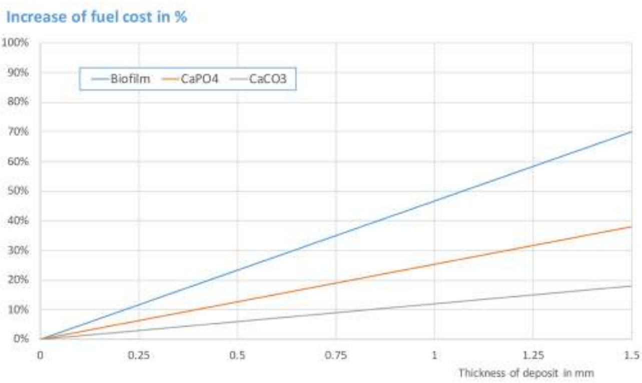

Figure 2. Cost impact of deposits on a condenser surface.

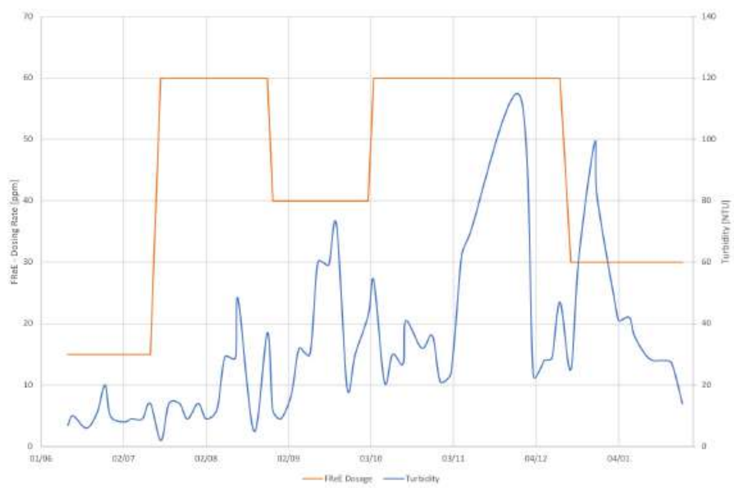

Figure 3. Effect of FReE dosage on the cooling water turbidity.

In addition to Equation 1, the air itself also contains particles, which are washed out and dispersed in the cooling water as suspended solids.

All of the above create critical conditions, especially inside the cooling tower filling labyrinth, as several factors meet together in one place: concentration increase, availability of fouling material, large surfaces and low flow velocity.

A new concept

Kurita has developed a new easy to apply online cooling system cleaning programme, named FReE, which stands for Fouling Removal Efficiency. The treatment has a range of Turbodispin® D – polymers for dispersion of inorganic deposits and suspended solids.

With this combination of products and technologies, FReE is able to remove practically any type of deposit (Al-Silica, sulfate, biofouling, algaes, $CaCO_3$).

The concept can be either used as standalone online cleaning programme or as a top up of a Kurita water treatment programme, e.g. as preventive action after product leakages. The technology is compatible with any of the company's other cooling water treatment programmes and is built on four basic pillars, as shown in Figure 1.

The technology is based on filming technology which shows several advantages. The main product of the new technology removes biofouling and acts as a dispersing agent. The dispersant and biodispersant effects are obtained as the active groups of the new product have a higher affinity to the metallic surfaces than the biofouling or corrosion products. FReE products penetrate slowly in between the metallic surface and the deposits and separates the deposit from the surface. As a result, the sediments are gradually and gently dissolved and removed from the system. The remaining deposits, due to its now porous structure, become fragile and are also removed step by step through the supporting dispersant for the inorganic matter. No system shutdown is required.

The high affinity of the active ingredients towards the metallic surfaces forms a complete film corrosion protection 'barrier'. This physical (molecular) barrier between the metal surface and the water minimises impacts of any critical situation, such as product leakages or times of high biofouling (e.g. spring).

The system is undergoing a slow and continuous cleaning process, which can last weeks and months. However, costly shutdowns are being avoided with the online cleaning treatment.

Application study

This application study shows how FReE can help to remove biofouling deposits inside a cooling tower. Two open cooling towers in an industrial area with an open sea nearby suffered intense episodes of biofouling growth. The biofilm accumulated in the cooling tower filling of the system and severely increased the water consumption. The production management of the company was worried about the low performance of its primary cooling system and asked Kurita's local engineers to improve its effectiveness. The cooling demand was higher than in the previous years, and the support through an additional auxiliary cooling circuit became necessary all year round instead of just eight months as in the years before.

The continuous operation of the auxiliary cooling circuit caused an extra reverse osmosis (RO) water consumption of 25 000 m^3, meaning 33 000 m^3 additional water intake to the RO system, resulting in an additional estimated cost of €35 000.

Beside these costs, during the regular maintenance and cleaning operations it became increasingly difficult for the operators to completely clean the fillings, as these were usually completely covered with fouling deposits.

The water treatment originally in place consisted of a programme including a corrosion inhibitor and a biodispersant. Sodium hypochlorite at a level of 0.5 ppm residual free chlorine was dosed in a continuous mode. In addition, two organic biocides were applied alternatingly as shock dosages once per week.

To recover the cleanliness of the tower fillings, FReE technology was recommended and the following targets were agreed with the customer:

- Clean the cooling tower fillings online and reduce the fouling significantly.
- Improve the effectiveness of the biocides while keeping the system as clean as possible.
- Reduce the operating time of the auxiliary cooling system, resulting in water and energy savings.
- Decrease operators workload for necessary cleaning of cooling tower filling.
- Save money by less filling replacement (less sludge, more durability).

Figure 4. One clean cooling tower filling after a 5 month FReE treatment.

Table 1. System data

System data	Main system	Auxiliary system
System volume	500 m^3	40 m^3
Recirculating rate	1800 m^3/hr	750 m^3/hr
Delta temperature	8 °C	7 °C
Return temperature	40 °C	29 °C
CoC	7	8
Water consumption	175 000 m^3/yr	57 000 m^3/yr
Construction materials	Alloy, stainless steel, fibre, concrete	Alloy, stainless steel, copper, fibre, concrete

Start of the cleaning

Due to the massive contamination of the system, the dosage selected for the cleaning period was relatively high, with 25 ppm proportional to feed water in each of the systems.

First, the online cleaning for the primary circuit was started. An increase of the turbidity of the cooling water was observed and Kurita's biofouling online monitor Hydrobio® Advance consequently reported fouling-cleaning cycles. As more and more fouling in the system was being dissolved, it became necessary to install a bypass filtering system (20 µm pore size) to reduce the turbidity in order to fulfil the local Legionella regulation which requires the NTU (nephelometric turbidity units) to be below 15.

In the auxiliary system, the situation was more complicated and unforeseeable. The filling of the cooling system had not been cleaned for years as it is not possible to remove them from the cooling tower. So the only possibility of cleaning instead of a complete replacement was FReE technology.

The appearance of foam several hours after the beginning of the treatment indicated that the system was undergoing a robust online cleaning process. This again resulted in a significant increase in the values for suspended solids and turbidity. Therefore, it became necessary to install a bypass filter in the auxiliary system.

The treatment was followed up by Kurita's local engineer's fine-tuning and control of the dosing rates. As leading key performance indicator (KPI) parameters, the FReE concentration and turbidity were closely monitored. It was found that the turbidity depends on the amount of fouling and product saturation in the water.

Due to the interaction of the biocides with the dispersed biomatter and the suspended solids, it became necessary to increase the required quantity of biocide (sodium hypochlorite) to remain within the legal limit values during the online cleaning.

Before the next scheduled shutdown and after five months of FReE treatment, the operators started to check the filling to assess if it needed cleaning or replacement. They found that due to the online cleaning, the filling of the main cooling tower was in excellent condition and replacement was not necessary. The maintenance operators spent less hours than usual to check and clean the filling, and the fouling had decreased noticeably.

Conclusion

This article presented an effective online cleaning tool for cooling systems, especially for biofouling or organic matter. The technology slowly dissolves deposits and removes them from the system with the normal blow-down. No system shutdown is required.

The technology can clean otherwise unreachable places and is an excellent solution for biofilm removal. It can increase production efficiency due to reduced shutdown times for cleaning. Furthermore, it can save water and energy use due to an efficient cooling tower operation, and it reduces the working load of operators and increases the lifetime of CT filling, while reducing the need for replacement.