Cooling towers: How to keep the equipment fully functioning
Many industrial processes require machines and equipment that need cooling due to the large amounts of heat produced during operation. Cooling towers are heat removal devices, used to transfer residual heat from a process to the atmosphere. They are an essential part of the production process and are therefore often considered to be critical equipment. In context, simply letting the cooling tower run until it breaks is not an option.

Cooling towers have very diverse applications. They are found in sugar and ethanol plants, thermoelectric and nuclear plants, steel mills, chemical and petrochemical industries, pulp and paper, among others. In addition to these, they are found in commercial and industrial air conditioning systems and in refrigeration installations.

In this eBook, we will look at the equipment, its operation, and the use of advanced technology for its monitoring and maintenance in order to ensure operational reliability.
Monitoring the condition of cooling towers
Cooling towers are systems that reject heat of fluids used in thermal processes. This need is found in a wide range of applications, from air conditioning from environments to power generation. Cooling towers are used in power plants sugar and ethanol, thermoelectric and nuclear plants, steel mills, chemical and petrochemical, paper and cellulose, food industries and others.

They are also found in air conditioning systems commercial and industrial facilities and in cold storage facilities.

For many of these applications, temperature control is indispensable and almost all production must be stopped if the temperature exceeds its tolerance limits. In such cases, cooling towers are considered critical machines for production continuity and for controlling the operating temperature of other critical equipment.

Therefore, guaranteeing the availability and reliability of these assets means avoiding damage to other machines, loss of process efficiency, production downtime and, consequently, financial loss.
Cooling towers have diverse configurations and operating principles. One of the most used types, due to its versatility and relatively low cost, is the mechanical draft tower for water cooling, whose function depends on electromechanical assemblies that require close attention from maintenance personnel.

These towers operate with the cold air flowing through a fill. The cold air makes contact with drops of hot water, creating two basic processes:

- Sensitive and latent heat exchange from hot water to cold air;
- Increase humidity of cold air;
The air flow is forced or mechanically induced by a centrifugal fan or driven by an electric motor. As the static pressure losses from these towers are low, the fan operates at low rotational speeds, around 120 to 300 rpm. To make this possible, the motor drives the fan with the aid of belt and pulley speed reducers or a gearbox.

In general, on axial fans, a diffuser is mounted with the function to direct and increase the speed of the air to the fan and to protect the blades. In centrifugal fans, these functions are performed by the volute.
Cooling tower operation is managed by the measurement and control of the temperature of the humid air outlet within pre-defined limits. This is done by regulating the air flow through the tower, whose electronic control turns off the fan when the lower temperature limit is reached and turns on the fan when the upper limit is reached.

In these cycles, the electric motor is subjected to a non-continuous service regime with several starts and stops in succession.

From a frequency converter in the drive motor, the fan operates at different speeds as a way of executing a proportional capacity control.
The electromechanical assembly formed by the motor, the gearbox and the fan are the biggest causes of defects that lead to maintenance shutdowns on cooling towers.

According to a study by Bristol-Myers Squibb (global biopharmaceutical industry) based on the monitoring of thirteen cooling towers (five with gearboxes and eight with belts), the biggest recurrence of failures in this set is related to the electric motor, followed by the gearbox.

Defects in motors and gear reducers are enhanced by the fact that they are subject to many matches, stops and load variations in a short time. In addition, gear units are typically mounted inside the tower, where they are exposed to the aggression of the humid environment with droplets of chemically treated water.

Fan defects are less recurrent, however the Pareto Principle applies: the least frequent cause is responsible for most of the effects, since most of the catastrophic failures in cooling towers are related to the fans.
The main defects of the fans are:

- Unbalanced blades;
- Inadequate inclination or elevation of blades;
- Cracked, corroded or broken blades

Blade imbalance can occur through many different causes: contaminant buildup, wear, cracking, corrosion, geometric imperfections and even the incorrect positioning of balance correction weights.

This type of defect is known to cause high amplitudes vibrations that propagate excessive dynamic stresses throughout the system. Without the right tools to detect and monitor the fan imbalance, its severity will increase leading to defects in other components, such as warping of the shaft and defects in bearings and gears.

Due to the large displacements resulting from unbalanced blades, the greatest operational risk under these conditions is the occurrence of repeated mechanical shock between the unbalanced blade and the diffuser. The stress generated by the shocks are concentrated in the body of the blade, close to the fan hub connection, where cracks begin to develop until the blade breaks as a result of fatigue.

A broken blade can damage other blades, the diffuser or an entire cell, forcing the reconditioning or replacement of various components, which is also synonymous with long maintenance downtime.

This type of failure can be caused by pauses in the fan or diffuser, a warped shaft or excessive resonance amplitudes during the start-up of the machine.

All of these defects have greater potential for catastrophic failure if the assembly is poorly designed. Two vibration frequencies important to the system are the motor rotation frequency (1xRPM) and the fan blade pass frequency (1xBPF).

Using an example of a motor with a rotation of 1700 rpm delivering power to a 6 blade fan rotating at 280 rpm, it gives a blade speed of 1680 rpm. This represents a difference of only 20 rpm between 1xRPM and 1xBPF.

When waves with close frequencies interact with each other, the phenomenon known as ‘beating’ occurs, in which their amplitudes periodically add up. In other words, the level of vibration is periodically amplified in relation to what would be observed without the beating phenomenon.

As a result, the already large vibration magnitude defects, such as blade imbalance, are also amplified, increasing the risk of catastrophic failure.
In gearboxes, the biggest concerns are gear and bearing defects.

Gearboxes are susceptible to excessive wear, cracking and tooth breakage. The main causes of these defects are overloading the gearbox and gear misalignment.

Gearboxes are often subjected to loads above those anticipated by the design, to enable increased production or to compensate for gear set sizing deficiencies. Misalignment between gears is commonly introduced after maintenance procedures that require disassembly and reassembly of components.

Bearings can be defective in their tracks, bearing elements and cages, with the root causes being related to lubrication failures: contamination, inadequate use of lubrication, insufficient lubrication, or lack of preventative maintenance.

These defects, when they occur prematurely, can also be symptoms of other defects in the assembly, such as unbalanced or misaligned fans in relation to the motor shaft.
Maintenance challenges in cooling towers
The cooling tower has the ecological and economical function of reusing water in industrial processes, re-circulating it in a closed circuit.

Within the various components involved in the operation of these towers, we can cite fans, motors, gearboxes and transmission shafts.

Normally, when the industry has a production process in place, the cooling tower linked to that process will also be in operation. A process can be linked to more than one cooling tower. But if one fails, the others do not replace it, potentially causing stress on the system and reducing the cooling capacity.

**SOME OF THE CHALLENGES FOR MAINTAINING COOLING TOWERS**

*Cooling towers are difficult to maintain due to:*

- The positioning of its high components;
- Components that are difficult to access, posing a risk to the maintenance operator;
- Lack of a secure platform from which to gain access;
- Elevated temperatures and humidity generated around the components;
- High levels of noise and vibration;
- The conventional vibration measurement model: costly and requires maintenance access to the component.
PROBLEMS ENCOUNTERED IN COOLING TOWERS

- Elevated operating temperatures that can lead to shorter operating cycles, premature failure and unscheduled shutdown;
- Excessive levels of sound and vibration, that could result in employee safety risks, fatigue and premature failure;
- Extreme temperature and humidity inside the cooling tower, which could rapidly degrade mechanical systems, affecting the noise level and bearing lifespan;
- Premature bearing failure and excessive wear of the pinion shaft;
- Inadequate lubrication;
- Unbalanced fans;
- Corrosion and erosion.
SAFELY MAINTAINING COOLING TOWERS

Keeping in mind the challenges listed, how can you identify failures prior to breakdown in a hard-to-access, if not inaccessible environment, with high levels of noise, temperature and vibration? Continuous and remote monitoring by wireless sensors is a perfectly appropriate solution. It will help with intervention and decision-making before an increase in temperature and vibration results in a costly breakdown, accident or more serious consequences.

When a gear unit requires repair or maintenance, it is necessary to hire a crane for removal and referral to a specialized service provider, usually one already hired by the industry. Hiring the crane, on top of the cost of removing the unit also carries operational risks.

Depending on the situation, it usually takes about two weeks to restore a problematic gearbox.

So why not make use of a market solution that brings a fresh approach to the maintenance of cooling towers?

For example, if the gearbox is monitored continuously and remotely, an assertive decision can be made regarding the prevention of failures. Unbalanced fans could be detected, among other problems. This reduces risks and costs as well as increasing reliability and continuity of the production process.
An appropriate response to address all of these challenges is to continuously monitor using the latest technologies available to the market. It is now possible to make use of sensors that are fixed to collection points, continuously gathering vibration signals in three directions as well as surface temperature. The sensors can wirelessly communicate to a virtual platform enabling visualization of the collected data.

Vibration and temperature sensors are commonly used to identify changes in how a machine is operating and can assist in monitoring and identifying defects in the motor assembly for the cooling tower fan. This is the value of the DynaPredict Bluetooth data logger, which has triaxial acceleration and temperature sensors, a three-year battery life and performs vibration spectra for analysis and interpretation in the comfort of a room away from the shop floor. Using this methodology:

- Reduces analyst exposure to risks related to excessive noise and hard-to-access components at height and inside the tower;
- Continuously measures the temperature of components, important in a thermal system;
- Eliminates the need to stop production for data measurement;
- Reduces the time spent by the analyst on the measurement process;
- The standard condition of the machine is known in all of the rotation and load scenarios in which it operates;
- Increases the understanding of failure modes and responsiveness of maintenance staff to defects, increasing the reliability of the equipment;
- Consequently, increases the availability of the machine by reducing downtime for corrective and predictive maintenance.
Solutions to increase reliability of industrial assets