Monitoring COOLING TOWERS Optimizes Safety and Reliability

Installing remote monitoring via a condition-monitoring system on wireless network provides a cost-effective means of control.

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Whether at a manufacturing facility, an industrial power plant or a public utility, the cooling system is a critical part of the operation. Heat is transferred from the process to the surroundings. Cooling towers cycle water through the manufacturing process and transfer the heat so that it can be released into the atmosphere. Because of the environmental, safety and profitability impact of failure, it is essential to keep these systems in operation.

Understanding and anticipating common failure modes make it possible to keep the plant operating at maximum capacity. Installing a condition-monitoring system can mean the difference between catastrophic failure and a planned shutdown.

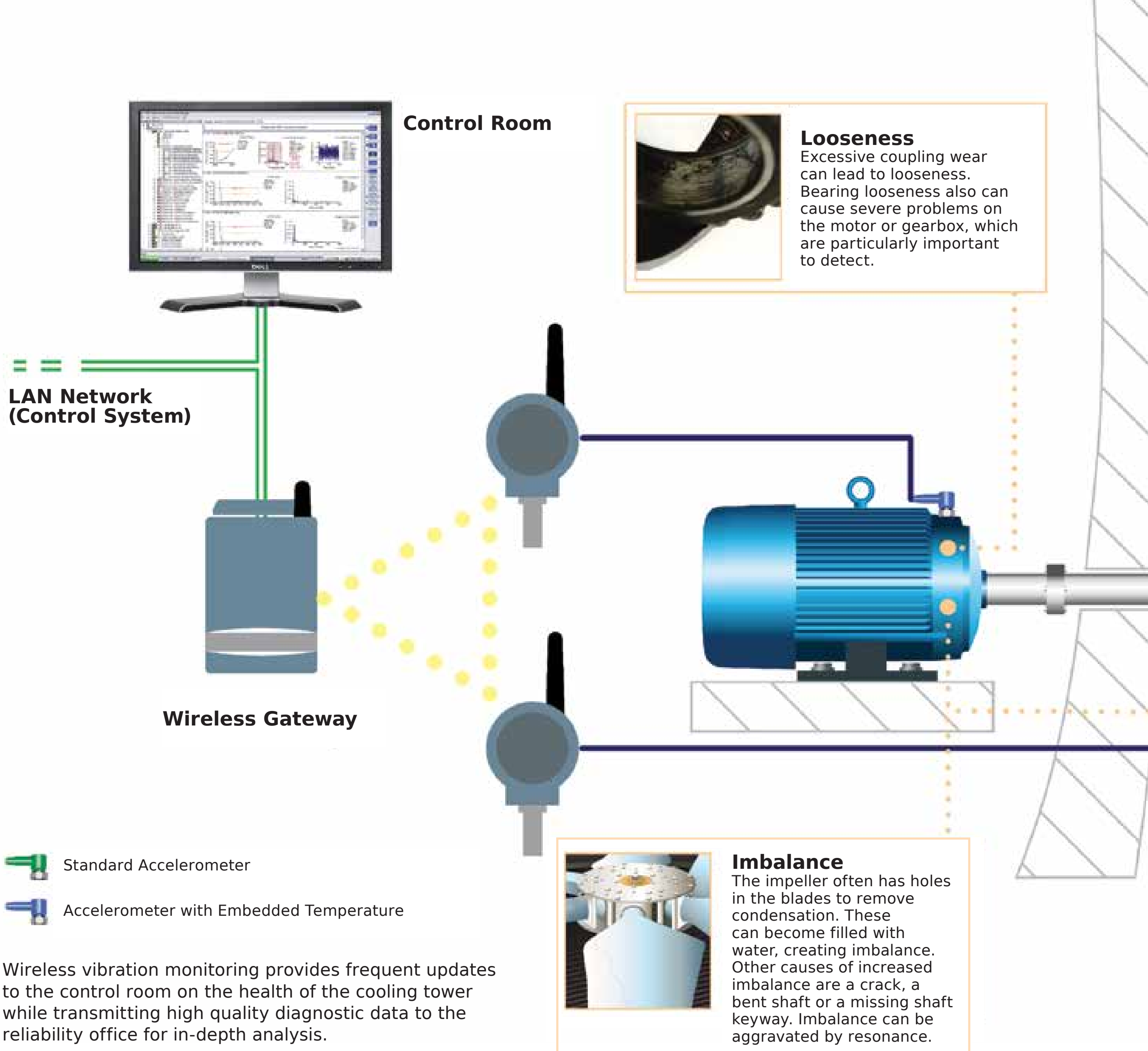
Operation and Failure Modes

While there are many types of cooling towers, the most common form is mechanical draft. These towers typically are implemented in banks mounted on an elevated platform. Each tower may incorporate one or more cells with the airflow driven by one or more fans. These enormous fans are driven by motors via a right-angle gearbox. Despite their relatively slow rotational speed, the fans possess immense inertia. When allowed to run to failure, this inertia is transformed into destructive force that can not only bring down the tower but also can compromise the structural integrity of the entire platform. Such an incident puts people in harm's way and translates into a prolonged process shutdown or slowdown until the damage can be repaired.

In a less dangerous scenario, tower failure still has a significant impact on production. The tower is not easily accessible, requiring specialized manpower and equipment to move and service. Because of the location and size of the equipment and the tower, a crane is often necessary to perform service. Operation is further compromised when replacement components have long lead-times, meaning that an unexpected failure – even when not catastrophic – could leave sections of the plant down for an extended period of time.

Regardless of the design, the root causes of failure are the same for both mechanical-draft and natural-draft cooling towers. The fan may fail due to prolonged exposure to moderate imbalance or due to extreme imbal-

Above: While the components of a cooling tower could be effectively monitored by trained personnel with portable vibration analyzers, the structure makes them difficult and dangerous to access.



Wireless vibration monitoring provides frequent updates to the control room on the health of the cooling tower while transmitting high quality diagnostic data to the reliability office for in-depth analysis.

ance caused by damage to one of the fan blades. Misalignment of the long shaft between the motor and gearbox, referred to as the jackshaft, also can lead to excessive coupling wear. However, the most common culprit is the gearbox itself, which can suffer from broken, chipped or worn gear teeth as well as defects in the bearings. These issues frequently find their root cause in insufficient lubrication.

Regardless of the cause, when any portion of the system fails, it can quickly lead to catastrophic damage to the entire system. For this reason, it is unwise to operate a cooling tower without some type of monitoring. The preferred solution for detecting these types of failure modes is vibration monitoring.

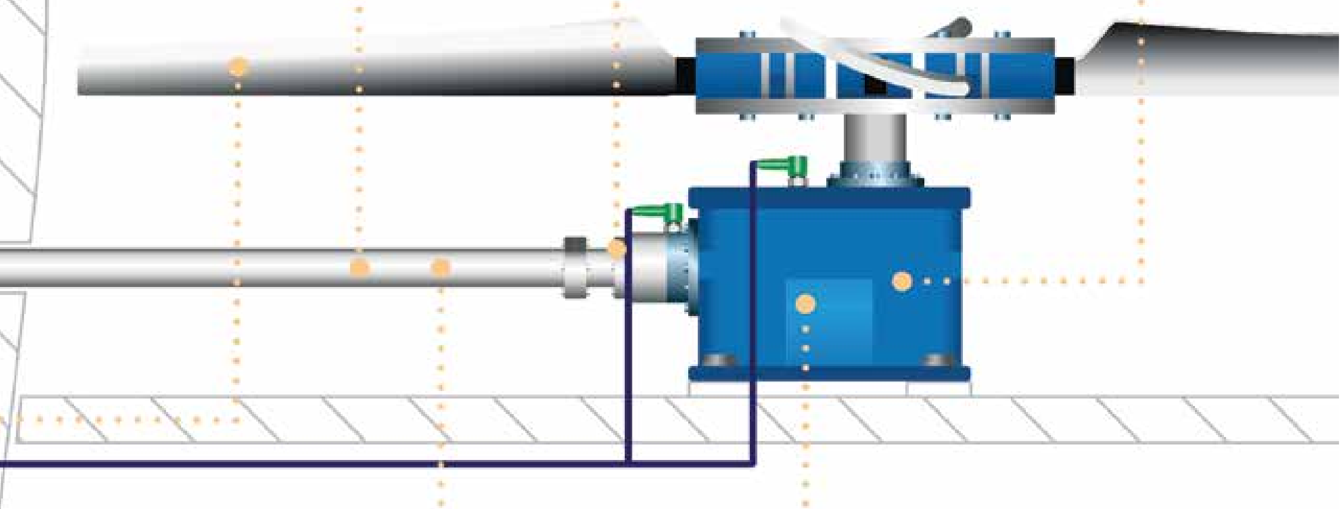
Periodic Monitoring

While the components of a cooling tower can be monitored effectively by trained personnel with portable vibration analyzers, the structure makes them difficult and dangerous to access. Cooling towers are almost always remote from the remainder of the operation, requiring time and effort to reach the area. Furthermore, the most important components – the jackshaft, gearbox and fan – are all inside the shroud. So, even if there were a safe way to access them during operation, it would be like standing in the eye of a hurricane. Therefore, the preferred solution

Bearing Defects
Bearings often operate under heavy, variable load and extreme environmental conditions. Because of the force applied to the bearings in a cooling tower, defects often progress quickly and lead to friction, bearing damage and gearbox failure.

Shaft Misalignment
Due to the length of the shaft in a cooling tower and the thermal changes that the shaft experiences, misalignment is a common issue. Stress inside the shaft can damage couplings, cause bearing fatigue and even lead to shaft breakage.

Broken/Chipped/Worn Teeth
Shaft misalignment causes increased load on the input gear, which causes bad meshing on the gears and generates debris. Damaged and misaligned gears can result in failure of the gearbox.



Coupling Issue
Excessive shaft misalignment can damage the coupling, which can lead to shaft separation. Severe coupling damage can lead to gearbox failure, damaged shafts and rotor cracks.

Insufficient Lubrication
The extreme conditions of the cooling tower often lead to issues with lubrication. Bearing wear and gear teeth damage caused by insufficient lubrication to premature equipment failure. The inaccessibility of the cooling tower makes it virtually impossible to perform accurate grease and oil analysis.

for cooling towers must include some type of automated monitoring.

Automated Monitoring via Vibration Switches

The most basic form of automated monitoring is referred to as a vibration switch. These basic systems, which have been in use for decades, typically utilize a simplistic operating mechanism: an embedded sensor detects excessive vibration and can shut off the unit.

While this solution is better than no monitoring at all, vibration switches have several disadvantages. First, they are only sensitive to lower-frequency vibration. This means that they are blind to virtually all of the key failure modes – gear defects, bearing faults and underlubrication –that generate higher-frequency vibration. This type of monitoring could be compared to running without a gas gauge: at some point, the car will run out of gas – but always without warning. In fact, the operator is only notified after the fact that the cooling fan has tripped. Therefore, while a vibration switch might help the plant avoid catastrophic failure, it provides no advance notice to optimize maintenance and minimize the operational impact.

One of the biggest advantages to vibration switches – their maintenance-free operation – also can become their biggest drawback. Despite their simplistic design, continual exposure to water and chemical vapors can eventually lead to corrosion. Because vibration switches typically are unmonitored, the first indication that a switch is defective might occur when the fan runs to failure.

Getting to the Root Cause with Remote Monitoring

Remote monitoring of cooling towers is the best way to ensure that developing faults are addressed before they can lead to failure. A vibration-monitoring system can detect all of the failure mechanisms previously discussed. Distinctive alerts can be sent to the control room, where a trained analyst can review the vibration signal to positively identify the nature and severity of the defect. However, the remote location of the cooling towers can make the cost of running wires prohibitive.

Fortunately, new developments in wireless technology offer a cost-effective way to reap the benefits of remote vibration monitoring without incurring the wiring costs. A traditional cooling tower monitoring system that might have encompassed miles of communication cables can now be replaced with a series of wireless vibration transmitters and a gateway. The gateway requires only one Ethernet cable, and it can be strategically placed near the control room. Wireless vibration monitoring provides frequent updates to the control room on the health of the cooling tower while transmitting high quality diagnostic data to the reliability office for in-depth analysis.

Wireless vibration transmitters can publish a number of trend values to the control room, where the condition-monitoring system can compare the current values with predefined alert limits.

The resulting alerts are only meaningful if they are conclusive and they translate into specific, immediate actions, of course. To meet this qualification, a vibration transmitter needs to publish at least two types of parameters:

- **Low Frequency.** Similar to what is monitored by a vibration switch, a low-frequency vibration parameter warns primarily about fan imbalances.
- **High Frequency.** A high-frequency vibration parameter captures impacting signals generated by root-cause problems such as bearing faults, gear defects and under lubrication.

The high-frequency parameter, which is typically measured in peak-acceleration, is of particular importance to the operation: it represents the level of impacting occurring on the gearbox and other components. It is important to note that a piece of rotating equipment that is properly installed and well lubricated should have little to no impacting. From this, we deduce the "Zero Principle" because the impacting on a good machine should be at or close to zero.

Furthermore, when the level of impacting reaches double digits, it can be assumed that a root-cause defect is developing on the machine. Each time the amplitude of the impacting doubles, it represents an escalation in the criticality of the defect. This leads to the "Rule of 10s," which is summarized in table 1.

TABLE 1. The Rule of 10s

Level of Impacting (g's Peak)	Interpretation	Action
10	Abnormal Situation Present	Alert Maintenance Team
20	Serious Abnormal Situation Present	Define Maintenance Plan
40	Critical Abnormal Situation Present	Implement Maintenance Plan

Using these simple rules, a control-room operator can effectively monitor the health of the cooling tower. This allows the maintenance team to define and implement an optimal maintenance plan to minimize cost and maximize production.

In conclusion, cooling tower failure is simply not an option. Process upsets coupled with potential harm to personnel, property and the environment are not an acceptable risk.

Condition-monitoring options are easier to implement, more robust and more cost-effective than ever before. Installing remote monitoring via a wireless network provides the control room with simple, meaningful alerts that make it possible to avoid the day every plant with a cooling tower hopes never comes.

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This article is the second part in a series that discusses how WirelessHART can help monitor and control various processes in the facility. Look for the first installment, which discussed using WirelessHART technology for monitoring steam traps, in the May 2015 issue of ***Process Heating****.*