Induced Draft Cooling Tower and Air-Cooled Heat Exchanger Monitoring Application Guide

Table of Contents

1 Description of “Wet” Cooling Tower Fans ........................................... 2
2 Air-Cooled Heat Exchanger (ACHE) ..................................................... 2
3 Induced Draft Fan Monitoring Challenges ........................................... 3
4 Failure Modes – What We Can Detect .................................................. 4
  4.1 Fan ........................................................................................................... 4
  4.2 Cooling Tower Gearbox ........................................................................ 4
  4.3 Belts and bushings ................................................................................. 4
  4.4 Motor ...................................................................................................... 5
5 Selecting the Proper Transducer and Monitor Solution ................... 5
  5.1 Transducer selection ............................................................................. 5
  5.2 Monitor selection .................................................................................. 6
  Protection System ...................................................................................... 9
  Management System Only ....................................................................... 9
6 Appendix and supporting information ............................................. 10
  6.1 Monitoring solutions ........................................................................... 10
  Protection .................................................................................................. 10
  6.2 Sensors .................................................................................................. 12
    190501 Velomitor CT: .............................................................................. 12
    200350 and 200355 Accelerometers ...................................................... 13
    200155 Accelerometers .......................................................................... 13
    AM1-100-T2 Accelerometer (Commtest) ............................................. 14
    AM3100T2-Z2 (Commtest) .................................................................... 14
    AS3100S2-Z2 (Commtest) ..................................................................... 14
7 Cooling Fan In-Depth Analysis ........................................................... 15
  7.1 Cooling tower description and operation ........................................ 15
    Types of Towers ....................................................................................... 16
    Natural Draft Towers .............................................................................. 16
    Mechanical Draft Towers ......................................................................... 16
  7.2 The cooling tower mechanical system ............................................. 16
  7.3 Problems associated with cooling tower mechanical systems ....... 17
    Fan assembly related problems .......................................................... 17
    Non-mechanical cooling tower problems .......................................... 17
    Fin fan operation and description ....................................................... 17
  7.4 Observations ......................................................................................... 18
    Changing Attitudes: .............................................................................. 18
Abstract: Industrial fans provide important cooling to a variety of processes throughout the power generation and oil and gas industries. Production is often reduced or curtailed when fans fail and cooling capacity is reduced.

Two very common types of fan categories are the mechanical induced-draft, evaporative type (commonly referred to as cooling tower fans) and the air-cooled heat exchanger type (ACHE or fin fans*). Both asset types present unique challenges when selecting the proper solution for fan assembly monitoring.

Note: Another cooling tower variation is the forced draft cooling tower where the fan is located at the air inlet rather than the air outlet. These cooling towers are not covered in this guide.

The purpose of this document is to help Sales Managers/Channel partners apply the proper solutions to their customers’ unique fan protection and condition monitoring problems for GE’s Bently Nevada product line.

Note: Machinery protection is implemented when vibration (or other) instruments are installed permanently onto a machine and connected to a dedicated monitoring and protection system. The protection system has alarm setpoints, which are set by the machinery OEM or the end user to automatically raise an alarm when the predetermined alarm level is reached. The system has alarm relays for alert and danger conditions that can initiate an automatic shutdown or trip of the machine; alternatively, instructions to shut down the machine may be acted upon by an operator when an alarm occurs. Machinery protection is necessary and valuable since it may prevent or minimize machine damage and consequential losses in the event that a sudden machinery or process malfunction occurs.

Safety: Cooling towers are dangerous places. Fans are on top of the fan deck, which requires climbing stairs. Sensors are mounted inside the fan stack, and safe access to the gearbox can be difficult.

ACHEs often are installed well above grade level and require climbing ladders or steps to access the sensor locations.

1 Description of “Wet” Cooling Tower Fans

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers evaporate water to remove heat from a process or machine.

Large amounts of air must be moved through a cascade of water to provide adequate evaporation and the desired cooling. The prime mover of air is the cooling tower axial fan assembly, which is mounted on the upper deck of a cooling tower.

The fan is typically seven or more blades with a radius of about 5 to 30 feet. The fan is situated horizontally inside a cylinder-like fan stack (or fan housing) on top of a right-angle, speed-reducing gearbox.

A long drive shaft or propeller shaft passes through to the outside of the fan stack and connects the gearbox to an electric motor. In some cases, the motor and fan assembly are both inside the fan stack.

The motor turns the shaft, and torque is transmitted through the speed-reducing right angle gearbox, turning the fan at speeds of 60 to 300 RPM. The fan produces a strong upward draft that exits at the top of the fan stack, rejecting heat and water vapor into the atmosphere.

2 Air-Cooled Heat Exchanger (ACHE)

Unlike the cooling tower, the ACHE is a “dry” fan that simply moves air over tubes that contain hot process fluid. Heat is removed from the process fluid as the air passes over the tube bundle. The cooling is often aided by fins that are attached to the tubes. The fins increase the cooling surface area and are the
reason some ACHEs are called “fin fans.” An ACHE operates on the same principal as that of an automobile radiator.

Fans are mounted below (forced draft) or above (induced draft) the heat exchanger, as shown below.

Generally speaking, ACHE fans are usually smaller and operate at a higher speed than cooling tower fans. The fan is powered by an electric motor and is often belt-driven, with some using a right angle gear drive. ACHEs often are mounted in “banks” where multiple fans are arranged in long rows. ACHEs often are mounted well above grade so that the hot air is ejected high enough to not cause problems with people or surrounding assets.

3 Induced Draft Fan Monitoring Challenges

Environment: With induced draft cooling tower fans, most of the monitoring focus is on the gearbox, and the gearbox is located within the fan stack. The warm, moist environment inside the fan stack is very turbulent. Algae, bio fouling and corrosion are the biggest problems to overcome when installing vibration sensors in a cooling tower. Protecting the sensor connector and cable is very difficult because even the best connector/cable system will succumb to the environment over time. An integral connector/cable is the best choice for sensor longevity, but not the easiest to install or maintain.

When instrumenting an induced draft ACHE, the sensor could be exposed to a temperature that exceeds the limits of our sensors, so it is important to know the temperature limit and choose the appropriate sensor.

Rotational speed: For cooling towers, sensors must be able to detect high-frequency gear and bearing faults and at the same time detect very low-speed fan-related faults. ACHE speeds are usually well within our sensor frequency range.

Location: Where to locate the monitor system is always a concern. Mounting it up on the fan deck is easiest and most cost-effective from a wiring point of view, but fan decks present a safety hazard to people who need access to the monitoring system and expose the monitoring system to a corrosive, wet environment. Mounting the monitors at a central location at grade level is the most convenient, but also is the most expensive, considering the electrical implementation requirements.

Note: Sensor cable lengths of more than 100 feet should be reviewed carefully against the transducer data sheet to assure the signal is not attenuated, causing a loss of critical sensor signal.
4 Failure Modes – What We Can Detect

The central component of a cooling tower fan is the gearbox. This is often a high-maintenance source due to aerodynamic loading from the fan, excessive loading on the gear teeth, and improper alignment of the gearbox to the motor. Many gearbox failure modes are secondary in nature. For instance, the failure of an intermediate shaft lower bearing allows the gearing to operate off parallel axis, and hence the gear teeth fail due to poor distribution of load. The gearbox is always located within the cooling water stream requiring special consideration for mounting a vibration sensor. Also, the environment is usually caustic due to chemicals added to control the pH level of the cooling water.

A vibration sensor must be able to measure the expected gear mesh frequency, blade passage, and bearing defect frequencies. Other frequencies of interest include fan balance and motor alignment. Gear and bearing defect frequencies tend to be the highest frequencies, while the fan balance frequencies are the lowest to be monitored. The other frequencies are found scattered between these extremes.

Monitoring of the gearbox can be accomplished by installing accelerometers at both the input and output shaft in a horizontal orientation. The output signals from these sensors can be routed to a protection monitor for the purpose of shutdown due to high vibration or terminated at some convenient location for interfacing with a portable vibration data collector or scanning system.

Example of gear frequency calculation:

- The highpass corner frequency of the gearbox seismic transducer should be below the running speed of the fan. For example, if the fun turns at 120 RPM, the highpass corner of the accelerometer would need to be less than 2 Hz. This is also required to detect problems with the fan.
- The lowpass corner frequency should be higher than 3X the highest mesh frequency, but monitoring at a minimum of 2.25 X GMF will give ample indication of an early gearbox issue. For example, a sample cooling tower gearbox from a plant in Texas has a motor speed of 1,780 RPM and 16 teeth on the pinion. This means that the mesh frequency is 474.7 Hz and that the 3X mesh frequency is 1,424 Hz.

4.1 Fan

The most common industrial cooling fan failure modes typically involve gearboxes or fan blades and are catastrophic in nature. In many cases, this type of failure leaves the gearbox and/or fan blades lying in the cooling water pond at the bottom of the tower or above a heat exchanger.

These failure modes are detected using a standard piezoelectric accelerometer or a Velomitor sensor. These sensors can be chosen to encompass the entire frequency range of expected defects and used to either protect or monitor for condition based maintenance.

4.2 Cooling Tower Gearbox

4.3 Belts and bushings

Belt-related failure modes are somewhat common in industrial fin fan applications. In general, belts used with these machines can be categorized into two different types: standard V-belts and timing or gear belts. V-belt frequencies are always below the RPM of either the motor or the driven machine. When they are worn, loose or mismatched, they normally cause three to four multiples or harmonics of belt rotation frequency (see inset).

---

1 Reliabilityweb.com
2 Reliabilityweb.com
Belt Frequency =
3.14 x Pulley Speed x Pulley Diameter/Belt Length

In this scenario, two times belt frequency is often the dominant peak. Amplitudes are normally unsteady and sometimes will pulse with either the driver or driven RPM. In regards to timing or gear belts, wear or pulley misalignment is most commonly indicated by high amplitudes at the timing belt frequency (see inset).

Timing Belt Frequency =
# of Sprocket Teeth x Shaft RPM

Another defect frequency is misalignment of pulleys and pulley eccentricity, which typically results in excessive run speed vibration in the axial direction and the radial direction respectively.

4.4 Motor

Motor vibration frequencies of interest include motor unbalance, rotor bar defects, output shaft alignment, and bearing defect frequencies. A complimentary continuous/scanning monitoring approach typically should include one accelerometer per bearing location. Mounting orientation for the accelerometers should be horizontal at the bearing since this is usually the axis that is most compliant. As the motor speed is usually 1800/1500 RPM, economical standard accelerometers can be used.

Figure 9. External Cooling Tower Motor
Cooling Fan Motor images pix-hd.com

5 Selecting the Proper Transducer and Monitor Solution

5.1 Transducer selection

GE has a wide range of accelerometers that can detect the major gearbox and fan failure modes. All of the accelerometers in this document have a “low end” frequency response of between 12 and 90 RPM, allowing them to detect 1X amplitudes in most applications. All accelerometers are capable of taking advantage of the Enveloping signal processing feature provided by the several of the GE and Commtest monitor solutions.

The Velomitor CT is a velocity transducer designed for cooling tower applications. It provides a good signal at the lower end of the frequency response curve and is the best choice for protecting the fan from large imbalance or blade separation problems.

The Velomitor CT signal is not compatible with acceleration enveloping.

Select the cable and connector type that can withstand the harsh CT environment. The CB2W100 cable assembly is an excellent choice for most two-pin MIL accelerometers used in cooling tower monitoring and protection. The Velomitor CT is designed to interface with conduit for added protection of the connector and cable. Commtest provides some excellent accelerometer choices.

Figure 10. Typical 190501 Velomitor CT installation
See the transducer detailed description in the appendix for more information.
## Sensor Chart

<table>
<thead>
<tr>
<th></th>
<th>190501 Vel CT</th>
<th>200350</th>
<th>200355</th>
<th>200155</th>
<th>AM1-100-T2</th>
<th>AM3100T2-Z2</th>
<th>AS3100S2-Z2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>100mv/in/sec</td>
<td>100mv/G</td>
<td>100mv/G</td>
<td>100mv/G</td>
<td>100mv/G</td>
<td>100mv/G</td>
<td>100mv/G</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±5%</td>
<td>±20%</td>
<td>±5%</td>
<td>±12%</td>
<td>±5%</td>
<td>±5%</td>
<td>±10%</td>
</tr>
<tr>
<td>Freq. Response</td>
<td>1.5Hz-1.0kHz</td>
<td>0.5Hz - 10kHz</td>
<td>0.2Hz - 10kHz</td>
<td>1.5Hz - 10kHz</td>
<td>0.4Hz - 13kHz</td>
<td>0.4Hz - 14kHz</td>
<td>0.7Hz - 10kHz</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>±2.5 in/s, peak</td>
<td>±50g, peak</td>
<td>±50g, peak</td>
<td>±20g, peak</td>
<td>±80g, peak</td>
<td>±80g, peak</td>
<td>±80g, peak</td>
</tr>
<tr>
<td>Exit</td>
<td>Top</td>
<td>Top</td>
<td>Top</td>
<td>Top</td>
<td>Top</td>
<td>Top</td>
<td>Right</td>
</tr>
<tr>
<td>Pricing</td>
<td>$$$</td>
<td>$$</td>
<td>$$$$$</td>
<td>$$</td>
<td>$</td>
<td>$</td>
<td>$</td>
</tr>
</tbody>
</table>

**Note:** Despite the datasheet range specified, practically it is very difficult to use an accelerometer to measure vibration at fan speed. For example: If a fan is running at 120 RPM (2 Hz) and moving 2mm (80 mil) pk-pk, an accelerometer with a scale factor of 100mV/g will produce a signal of 1.6mV. A Velomitor CT with a scale factor of 500 mV/in/sec will output a 250 mV signal. Practical experience has shown that the noise floor for permanently installed sensors can be as high as 5mV so it is very difficult to determine the low speed shaft motion with an accelerometer. It is preferable to monitor the output shaft with a Velomitor CT and the input shaft with an accelerometer rather than using an accelerometer on both shafts. An accelerometer, however, is necessary for acceleration enveloping, which is useful in detecting certain gear problems. Select a sensor or combination of sensors that have the necessary frequency response to detect the faults of interest.

### Accelerometer Mounting Caution
Careful consideration must be given to the mounting arrangement. A poorly mounted sensor can have a much lower mounted resonance compared to the stated value in the datasheet.

### Keyphasor
If the cooling tower is especially large or critical (and this is rare) or if the unit is a variable speed, a Keyphasor should be installed to capture the fan speed. This makes it easier to detect and differentiate gear faults and bearing faults, especially on gearboxes with an intermediate shaft.

### 5.2 Monitor selection

The criticality ranking of the fan is often the deciding factor when considering monitoring solutions.

If the customer needs machinery protection, the best choice is the 1900/65A with Velomitor CT sensor or a combination of Velomitor CT & accelerometers.

Fan criticality will determine the best choice: machinery protection, machine condition monitoring, or simply doing nothing.

Cost is often a factor in the monitor selection process. At a minimum, customers will want a cost-effective solution to monitor the health of the gearbox and have some indication of significant events (such as blade/hub separation) requiring immediate attention. In some cases, protection is required, for instance when upgrading from vibration switches to more sophisticated monitoring systems.

**Note:** The recently introduced 2300 Series vibration monitor provides many of the features of the 1900/65A monitor and may be a consideration for a CT or fin fan application. The 2300 Series does not currently support Velomitor sensors, proximity sensors or temperature. However, these enhancements are planned. Check with the FAE or Product Line Manager to determine the suitability of the 2300 Series in a low speed fan application.
Below is a monitor/transducer compatibility and criticality chart to help determine the most appropriate solution.

**Monitor/Transducer Compatibility Chart**

<table>
<thead>
<tr>
<th>Sensors</th>
<th>1900/65</th>
<th>2300</th>
<th>DSM</th>
<th>Vb Online</th>
<th>Scout</th>
</tr>
</thead>
<tbody>
<tr>
<td>190501 Velomitor CT</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>200350</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>200355</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AM1-100-T2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AM3100T2-Z2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AS3100S2-Z2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ranger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>200155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criticality</th>
<th>1900/65</th>
<th>2300</th>
<th>DSM</th>
<th>Vb Online</th>
<th>Scout</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (Protection)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>H (Monitoring)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
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</table>

**Monitor Solutions Chart**

<table>
<thead>
<tr>
<th>Protection</th>
<th>1900/65a</th>
<th>2300</th>
<th>DSM (direct input card)</th>
<th>vbOnline*</th>
<th>SCOUT 100/140*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cond Mon</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Tower App</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>ACHE App</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Enveloping</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Band Pass</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Input Channels</td>
<td>4</td>
<td>2</td>
<td>32</td>
<td>16</td>
<td>2/4</td>
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<tr>
<td>Relays</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Modbus</td>
<td>X</td>
<td>Q1 2016</td>
<td>X</td>
<td>Only as input</td>
<td></td>
</tr>
<tr>
<td>Software Interface</td>
<td>None</td>
<td>System 1*</td>
<td>System 1*</td>
<td>Ascent</td>
<td>Ascent</td>
</tr>
</tbody>
</table>
# Monitor Solution Strengths and Limitations

<table>
<thead>
<tr>
<th>Solution</th>
<th>Strength</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| 1900/65A                  | • Machine protection  
                          • Vibration and temperature  
                          • Enveloping  
                          • Local display  
                          • Modbus communications | Difficult to interface with GE’s System 1* machinery management software (S1) |
| 2300 Series vibration monitor | • Monitoring and protection  
                          • Two acceleration inputs  
                          • Synchronized sampling  
                          • One Keyphasor/speed channel | • No Velomitor input  
                          • No proximity input  
                          • No temperature input (these are planned enhancements) |
| vbOnline                  | • High channel density  
                          • Small footprint  
                          • Easy to configure  
                          • Enveloping  
                          • Accepts wide variety of sensors  
                          • Low cost per channel | • No protection  
                          • Requires Ascent to view data |
| DSM                       | • High channel density  
                          • Enveloping  
                          • Low cost (Modbus)  
                          • Modbus communications | • No protection  
                          • High cost (if S1 needed) |
| SCOUT                     | Condition monitoring and diagnostics | • Walk around  
                          • No access to CT gearbox |

## General Decision Tree

![General Decision Tree Diagram](image-url)
**Protection System**

**Example Case 1: 1900/65A monitor**

<table>
<thead>
<tr>
<th>Item No</th>
<th>Qty</th>
<th>Model No</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1900/65A monitor</td>
<td>General purpose vibration monitor</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>200350</td>
<td>Accelerometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 on Gearbox, 2 on Motor</td>
<td>Typically 1 accelerometer on Motor DE side</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>CB2W100-xx</td>
<td>Accelerometer cable, xx (= length option)</td>
</tr>
<tr>
<td>4-1</td>
<td>1</td>
<td>168628</td>
<td>Stainless steel NEMA 4X weatherproof door for panel-mount</td>
</tr>
<tr>
<td></td>
<td></td>
<td>display assembly</td>
<td></td>
</tr>
<tr>
<td>4-2</td>
<td>1</td>
<td>168944</td>
<td>Fiberglass NEMA 4X/IP66 weatherproof housing with window in door</td>
</tr>
</tbody>
</table>

**Management System Only**

**Example Case 2: Vb Online**

<table>
<thead>
<tr>
<th>Item No</th>
<th>Qty</th>
<th>Model No</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>KTOC0534</td>
<td>Vb Online 16 device (16Ch) - Complete Kit. 16 channels active with Level 3 Software</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>AM1-100-T2</td>
<td>Accelerometer</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>CB2W100-xx</td>
<td>Accelerometer cable, xx (= length option)</td>
</tr>
</tbody>
</table>

**Example Case 3: Dynamic scanning module (DSM) + seismic direct input card option**

<table>
<thead>
<tr>
<th>Item No</th>
<th>Qty</th>
<th>Model No</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>149744-aa-bb-05-dd-ee-ff-gg-hh</td>
<td>Dynamic scanning module + 1 seismic direct input card</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>200350</td>
<td>Accelerometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 on G/B, 2 on Motor</td>
<td>(Typically 1 accelerometer on Motor DE side)</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>CB2W100-xx</td>
<td>Accelerometer cable, xx (= length option)</td>
</tr>
<tr>
<td>4-1</td>
<td>1</td>
<td>168628</td>
<td>Stainless steel NEMA 4X weatherproof door for panel-mount display assembly</td>
</tr>
<tr>
<td>4-2</td>
<td>1</td>
<td>168944</td>
<td>Fiberglass NEMA 4X/IP66 weatherproof housing with window in door</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>3010-56</td>
<td>DSM Modbus exporter software</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>172555</td>
<td>Modbus serial-to-Ethernet bridge</td>
</tr>
</tbody>
</table>
6 Appendix and supporting information

6.1 Monitoring solutions

Protection

The 1900/65A General Purpose Equipment Monitor is designed to continuously monitor and protect equipment that is used in a variety of applications and industries. The monitor’s low cost makes it an ideal solution for general purpose machines and processes that can benefit from continuous monitoring and protection.

The 1900/65A monitor provides four transducer inputs and four temperature inputs. Software can configure each transducer input to support 2- and 3-wire accelerometers, velocity sensors or proximity sensors. Each temperature input supports Type E, J, K, and T thermocouples, and 2- or 3-wire RTDs.

The dedicated buffer output can provide the signal for each transducer input.

A Modbus Gateway option allows the monitor to provide static variables, statuses, event list, and time and date information directly to any Modbus client, including distributed control systems (DCSs), supervisory control and data acquisition (SCADA) systems, programmable logic controllers (PLCs).

Monitoring solutions

SCOUT is well suited for use in monitoring the condition or asset health of industrial cooling fans. It is categorized as a PVDC (portable vibration data collector), which lends itself well to the location where these fans typically are installed. From a convenience standpoint, these fans often are located in areas that are somewhat difficult to reach, requiring traversing stairwells and ladders.

Due its lightweight and portable form, SCOUT easily can be worn as an accessory for interfacing with permanently mounted sensors that are attached to the motor, gearbox or fan.

BNC connectors typically are routed to the exterior of the cooling tower or ACHE (air cooled heat exchanger) applications and easily can be connected to a SCOUT instrument for data collection.

This data collection most commonly is performed on a monthly basis but can be more or less frequent, based on the criticality ranking associated with the machine and available resources.

Due to the wide range of frequency response capable with SCOUT, and the ability to receive this data into Ascent vibration analysis software, all common fault modes associated with these equipment types can be measured, identified, and trended. SCOUT comes in two varieties, a two-channel device (SCOUT100) and a four-channel device (SCOUT140). They are essentially the same device, with the main differentiating factors being channel density and additional analysis capabilities for the SCOUT140.

vbOnline can be viewed in a very similar way to SCOUT. The main difference is that vbOnline is a permanently installed scanning solution that offers the opportunity for more frequency data collection.

This product is best used with machines ranked as mid-criticality but not requiring protection. As with SCOUT, vbOnline interfaces with Ascent for data housing, diagnostics and analytical approaches.

This is facilitated by an Ethernet TCP/IP connection to a plant LAN that allows two-way communications between vbOnline and the Ascent database.

Data collection is performed using the same piezoelectric accelerometers that typically are mounted at the motor, gearbox, or fan and can be scheduled based on condition-based parameters using the Ascent configuration portal.
Once configured, these schedules are maintained by the Ascent Online Manager service that can be housed on the Ascent database server. Data collection will be automated without the need for Ascent interaction and will continue until the service is either stopped or altered.

This data will be pushed into the Ascent database for viewing with the Ascent software. vbOnline comes standard with 16 input channels and can interface with any sensor providing an mv/EU signal. In addition, this monitor also can accept 4-20 ma signals and Modbus communications for entry into Ascent.

It also has two onboard tachometers or Keyphasor inputs for phase information or condition-based data collection and two relays that can be configured to annunciate an event of some type based on alarm conditions within Ascent.

The 149744 Trendmaster dynamic scanning module (DSM) is a compact rack-based data acquisition system that is fully integrated with System 1 software. The DSM rack has five card slots. The first slot is dedicated for communications and will accept either the copper or fiber Ethernet card. The other four slots are general-purpose card slots that can accept any combination of the available DSM input cards.

The DSM supports Seismic Direct Input Card 164746-01, which connects directly to sensors. Direct input cards support up to eight channels and provide very rapid scanning. All input card types offer high-resolution sampling with onboard real-time processing.

Onboard processing is the key to the powerful and efficient features available with the DSM platform. Because each input card can process data locally, the DSM can return post-processed variables to the host computer and reduce the required network bandwidth.

If the host computer requires raw data, the DSM also can return waveforms and spectrums.

The introduction of a Modbus digital interface now permits DSMs to communicate directly with process control and automation systems without the need for additional hardware.

This capability provides a low-cost entry-level alternative to System 1 software that uses the basic trending and alarming functionality that is integral to existing process control systems. All DSMs now include Modbus over TCP/IP capability and require only the DSM Modbus Exporter software to configure all the DSM inputs and define the Modbus interface.
6.2 Sensors

CAUTION: Any sensor that is installed within the wet environment of a cooling tower MUST have adequate connector protection or an integral cable. If the sensor connector is exposed to the humid and hot environment, the sensor lifetime may be greatly reduced due to corrosion of the connector.

190501 Velomitor CT:
The Velomitor CT velocity transducer is a low-frequency version of our standard Velomitor piezo-velocity sensor. Its design specifically measures casing vibration velocity on cooling tower and air-cooled heat-exchanger fan assemblies that operate at or above 90 rpm (typically 100 to 300 rpm). The Velomitor CT transducer can measure vibration amplitudes at these frequencies as well as the vibration frequencies generated by the fan motor and speed reducer.

**Frequency Response:**
1.5 Hz to 1.0 kHz (90 to 60,000 cpm) ±3.0 dB

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200350 and 200355 Accelerometers

The 200350 and 200355 accelerometers are general purpose, case-mounted seismic transducers designed for use with DSM Seismic Direct Input Card 164746-01.

The 200350 and 200355 accelerometers are contained within a hermetically sealed, stainless steel case. The design provides an extremely rugged transducer, well suited for harsh industrial environments. Each transducer’s top-mounted, two-pin connector (MIL-C-5015) allows for easy installation and removal of the interconnecting signal cable. A 1/4-28 threaded hole on the bottom of the casing accommodates multiple mounting options.

The 200350 and 200355 accelerometers contain a piezoelectric sensing device, which generates charge when subjected to vibration. This charge then is converted electronically to a differential voltage signal, which is proportional to the acceleration that is parallel to the sensitive axis of the transducer.

**Frequency Response:**
- 200350: 0.5 Hz to 10,000 Hz (30 to 600,000 cpm) ±3.0 dB
- 200355: 0.2 Hz to 10,000 Hz (12 to 600,000 cpm) ±3.0 dB

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**200155 Accelerometers**

The 200155 low-frequency accelerometer is designed for use only with Essential Insight.mesh wireless condition monitoring and should be used only for low speed applications such as heat exchanger fin fans.

The 200155’s broad frequency response requires a longer settling time for measurements and should therefore not be used unless low frequency response is specifically required by the application. The transducer features extremely robust construction, using a hermetically sealed, stainless steel case.

**Frequency Response:**

1.5 Hz to 10,000 Hz (90 to 600,000 cpm) ±3.0 dB

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**AM1-100-T2 Accelerometer (Commtest)**

**Frequency response:**

0.4 Hz to 13,000 Hz (24 to 780,000 cpm) ±3.0 dB

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**AM3100T2-Z2 (Commtest)**

General purpose accelerometer. 100 mV/g, top exit, +/-5%, 80 g peak acceleration range, 1/4-28 mounting thread. Large – 142 g, C1D2-rated.

**Frequency Response:**

0.4 Hz to 14,000 Hz (24 to 840,000 cpm) ±3.0 dB

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1. Top view
2. 19.1 mm (0.750 in) across corners
3. 11/16-inch hexagonal
4. Side view
5. 1/2-20 UNC-2A 5-pin connector
6. 3/8-24 UNF-2B threads, 7.1 mm (0.28 in) deep, minimum
7. 17.0 mm (0.67 in) diameter, typical
AS3100S2-Z2 (Commtest)
General purpose accelerometer. 100 mV/g, side exit, +/-5%, 80 g peak acceleration range, 1/4-28 mounting thread. Large – 145 g, C1D2-rated.

Frequency response:
0.7 Hz to 10,000 Hz (42 to 600,000 cpm) ±3.0 dB

7 Cooling Fan In-Depth Analysis
Heat dissipation is one of the most common processes in the industrial plant. Cooling towers and air-cooled heat exchangers (fin fans) are the two most common methods for removing waste heat.

Cooling tower and fin fan use is on the rise due to economic and environmental reasons related to heat removal. In a chemical plant or refinery, for instance, cooling towers provide the least expensive way of providing large amounts of chilled water to a processes’ heat exchange system.

Fin fans are best suited for applications where precise control of process liquids is required, such as in a styrene unit where the process liquid is fed directly into the heat exchanger.

Power generation facilities are using cooling towers in their efforts to comply with environmental regulations. Plants are no longer allowed free use of lakes, rivers, or other natural bodies of water for cooling water. If water from a natural source is used, it must be cooled before it is discharged from the plant.

Cooling towers are being installed to either comply with thermal discharge limits set by the EPA, or as part of a completely self-contained closed loop cooling water system that eliminates discharge. In areas where water is not available for evaporative cooling, fin fans can be used.

Some geothermal power generation facilities use fin fan cooling in this manner.

Because cooling towers and fin fans often are located in remote areas of the plant, they have traditionally not enjoyed the maintenance attention compared to other machines that are located within process unit.

However, plants can no longer afford to ignore these machines. They are simply too important to the process and too expensive to operate in a breakdown maintenance mode. The trend now is to apply the same modern maintenance techniques and tools to the heat removal systems that are being used on the process machinery.

This trend is creating demand for better products and services for cooling tower and fin fan maintenance.

It also is changing the way fans are monitored. Cooling tower and fin fan users are demanding better machinery monitoring capability for their fan mechanical systems. Two areas of concern for plant maintenance and operations are availability of the cooling system and safety.

On the availability side, the loss of a cooling tower fan means reduced heat extraction capacity, which often results in a loss of production. If a fan suffers a catastrophic failure, availability is curtailed while expensive repairs are completed. A catastrophic fan failure can cause significant structural damage to itself and the surrounding area.

At present, many users rely on the vibration switch as the device that hopefully will minimize tower damage once a vibration-causing event occurs. This is an acceptable solution in most cases assuming the switch performs its job when the time comes.
Unfortunately for fan users, the effectiveness of the vibration switch is a hit-or-miss proposition at best. Users have shared accounts of fan failures where the switch acted too late, or not at all, during a fan failure. What users want is a reliable monitoring system that can provide not only shutdown capability, but a pre-shutdown warning of increasing vibration amplitudes, access to the vibration signal for analysis, remote reset capability, a way to verify alarm set points, and a way to periodically verify if the monitor is operating properly.

Safety is also a concern. In order to manage a fan mechanical problem, operators need as much warning as possible to safely take a fan out of service for repairs. Effective shutdown capability is also a must for failures that happen instantaneously.

The industry needs a reliable fan monitoring system that can address the unique needs of cooling towers and fin fans. GE has the experience, knowledge and products to provide a quality fan monitoring and protection system.

7.1 Cooling tower description and operation

Cooling towers and fin fans are used throughout the refining, petrochemical and power generation industries as a means of dissipating unwanted heat to the atmosphere. Even though their objectives are the same, cooling towers and fin fans differ significantly in design and usage.

A cooling tower is a device for reducing the temperature of water by bringing it in contact with air. Most of the heat exchange in a cooling tower happens through the evaporative process when hot water is passed over cool air through a medium called “fill.” As water falls through the fill, air is blown across it by a fan. As the water evaporates, an exchange of heat takes place, the temperature of the water is reduced, and heat is rejected to the atmosphere.

The critical need for energy efficient cooling together with water conservation has increased the popularity of cooling towers.

The cooling tower is a large, framed structure with wood being the most common building material. Man-made materials such as steel, fiberglass, and concrete are becoming increasingly popular because the price of wood is increasing every year, and because the chemicals used to preserve the wood are being scrutinized by the EPA.

The fan deck is at the top of the tower and consists of the fan mechanical assembly and the fan stacks. Between the basin and the fan deck is the frame and support structure. The frame is enclosed with a wood or fiberglass casing at each end with louvered sides to allow air entry. The cooling section of the tower contains the fill. Where the fill is located within the tower depends on whether the tower is a cross-flow or counter-flow design. The bottom of a cooling tower consists of a concrete basin where the cold water is collected after passing through the tower.

Above the fill area is the hot water distribution system. The method of distributing the hot water to the fill is also dependent on tower design. The distribution system will be either a shallow pan-shape basin, located along the deck, that drops water over the fill, or it will be a system of spray nozzles mounted inside the frame below the fan stacks. Drift eliminators are located above the fill, and just below the fan stack. Drift eliminators prevent water droplets (unevaporated water) from escaping through the fan stack.

Cooling towers are divided into sections called cells. The cell is the smallest tower subdivision that can function as an independent unit with regard to air and water flow.

Each cell may have one or more fan stacks and one or more water distributions systems.

Types of Towers

Many factors determine the type, size, and shape of a cooling tower. The final choice is determined by many factors such as individual user requirements, economic considerations, local weather patterns, and aesthetics. The two basic cooling tower designs in use today are the natural draft tower and the induced-draft tower.

Natural Draft Towers

Natural draft cooling towers rely on natural forces to move air through the cooling section of the tower. The most recognizable example of the natural draft tower is the large hyperbolic tower used by many nuclear power generation stations. Hyperbolic towers work much like a chimney, where the air flow is induced by convection.

Natural-draft cooling towers are best suited for large water capacity requirements, where space is a limiting factor. Although simple in design and easy to maintain, the natural draft cooling tower’s use is limited by its high initial cost. Most towers in use today rely on fans to move air through the tower.

Mechanical Draft Towers

Mechanical draft towers rely on axial or centrifugal fans to move air through the cooling tower fill. Mechanical draft towers may be either forced or induced draft. Forced draft fans are used on smaller towers where there is more of a need to control the air flow (hence the temperature), and less of a need for high air exit velocities.

An induced draft fan has a high air exit velocity, which serves to push hot, humid air away from the tower, preventing it from recirculating into the tower. Induced draft towers are typically larger in size and provide larger air and water flow capacity.

Towers also are characterized by how air and water are brought together. In a cross-flow tower, air is mixed with a downward flow of water in a horizontal direction. Hot water is pumped to the top of the tower into a basin that runs along the length of the tower. Gravity feeds the water into the fill through small holes in the bottom of the basin. The cross-flow design usually provides a low resistance to air flow, enabling the tower to pass more air for a given amount of power when compared to the cross-flow design.

In a cross-flow tower, air enters the bottom of the tower and moves upward against the falling water. Hot water is distributed to the fill with a pressurized spray system that runs through the inside of the tower. This arrangement makes more efficient use of the fill because it places the coldest water at the bottom to the fill in contact with the incoming air, which is at the lowest wet bulb temperature. Counterflow towers have greater air resistance, and lower flow rates, than cross-flow towers.
7.2 The cooling tower mechanical system

As mentioned earlier, the larger field-erected towers use axial type fans to move air through the tower. The axial fans are part of a fan mechanical system consisting of an electric motor, drive shaft, couplings, gearbox, and mechanical support. A fan stack surrounds the fan assembly. The fan stacks are miniature versions of hyperbolic towers, which aid air movement through convection.

- **Fans:** Fan blades are made of aluminum, stainless steel, plastic or fiberglass. The length varies from 5 to 20 feet. Fan blades are designed to move a maximum amount of air with the least amount of power. Other design considerations include safety, noise abatement, erosion resistance, chemical resistance, interchangeability (balance), and UV resistance. Fan blades are fixed to a hub that maintains fan position and pitch. Typical fan tip speed is 12,000 fps, but due to OSHA noise restrictions, tip speeds are sometimes lowered to around 11,000 fps.

- **Motors:** Motors usually are furnished in accordance with the purchaser’s specification. Motors range from 50 to 200 hp, and typically use anti-friction type bearings. Motors operate at 1,800/1,500 rpm. Variable speed motors and motors that can be operated at half speed are being used more often as process control requirements demand tighter control of the cooling capacity. The motor is mounted on the same support as the gearbox but outside the fan stack and away from the wet cooling tower air stream.

- **Drive shaft and couplings:** Power is transmitted from the motor to the gearbox via a floating drive shaft. Drive shafts are made from stainless steel or composite materials. Composite shafts are becoming more popular because they are lighter than steel and less prone to bowing. Composite shafts can span 20 feet without the need of an intermediate support bearing. Couplings are typically the composite or steel disk type design.

- **Gear drives:** The gear drive purpose is to reduce the speed from the motor to a speed required by the fan. Gear drives also change horizontal rotation to a vertical direction. The most common gear drive on a large cooling tower is the double-reduction, right-angle drive utilizing spiral bevel or helical gears. Typical reduction ratio is 18 to 1. The 18-to-1 ratio provides a fan rotational speed of 90 to 100 rpm. Gear drive ratios below 10 to 1 can use a single reduction gear. These are used on smaller towers with faster fan speeds. Splash type lubrication is more common than forced lubrication.

The motors and pumps that deliver water to the water distribution system are also part of the cooling tower’s mechanical system.

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7.3 Problems associated with cooling tower mechanical systems

- Imbalance of the fan assembly
- Imbalance of the drive shaft assembly
- Misalignment between motor and gearbox
- Drive shaft bow.  
  **Note:** Drive shaft bow usually happens to steel or aluminum shafts that have been sitting idle. In the daytime, the sun will heat one side of the shaft, causing a bow. This can cause high vibration if the fan is started with a bowed shaft. Many users are installing composite shafts that resist bowing.
- Coupling failure
- Loose gearbox mount.  
  **Note:** Corrosion of fasteners holding the gearbox to the mechanical support are the main cause of this condition.
- Loose fan-to-hub hardware
- Loose motor mount

**Fan assembly related problems**

- Loose hub hardware
- Blade pitch change.  
  **Note:** Blade pitch change or irregularities will cause a 1X vibration component. This condition is similar to a balance problem.
- Fan blade-to-fan stack rub
- Fan blade erosion
- Fan auto-rotation (wind milling effect)
- Gearbox bearing wear
- Gearbox gear wear
- Gearbox lubrication failure
- Oil temperature
- Water ingestion
- Motor bearing failure
- Motor temperature problems

**Non-mechanical cooling tower problems**

- Water treatment
- Blow down disposal.  
  **Note:** Since the operation of a cooling tower depends on evaporation as the principal means of heat dissipation, chemicals present in the water will be concentrated. Blow down is cooling tower water that is discharged from the system to control concentration of salts, water treatment compounds, wood treatment chemicals, or other impurities in the circulating water. These compounds are used to maintain water quality, or are presented as dissolved solids in the makeup water.
• Bacteria control
• Corrosion control
• Wood deterioration
• Weather (wind, ice, sun)
• Improper water loading
• Drift escape
• Plume control.

**Note:** Plumes are the visible water vapor clouds that are discharged from the fan stack under certain weather conditions. The plumes are pure water vapor and are not harmful to the environment. However, these very noticeable plumes are perceived by the public as pollution. Cooling tower users take measures to abate the plume whenever possible to maintain public relations.

• Rain/precipitation
• Noise

**Fin fan operation and description**

Fin fans do not use the evaporation of water to provide cooling. Fin fans consist of several bundles of finned tube heat exchangers mounted in a fabricated metal box. Fin fans operate on much the same principal as the condenser unit of an air conditioning system. Air is moved across the heat exchanger with a motor-driven induced draft or with a forced draft fan. On an induced draft fin fan, the fan assembly is mounted above the finned tubes. Induced draft units minimize warm air recirculation and provide more precise process temperature control. Forced draft units operate with the fans below the tube bundles, and are better suited for higher inlet process temperatures because the fan assembly is not in the hot air path.

The fin fan mechanical system consists of a motor-driven axial flow, propeller type fan. V-belts transmit the power from the motor to the fan. The fan rotational speeds range from 200 to 400 rpm. In some cases, a small right angle gear speed reducer is used in place of the belts. The method used is determined by user preference. The belt system costs less but, the gear drive system is more reliable. The motor and fan assembly are mounted to a common support channel that runs across the structure's mid-section. Fin fans are used as single, standalone units, or bolted together in groups of two or three.

Fin fans are used to cool fluids other than water. They are used mostly for cooling process liquids in the refining and petrochemical industries. They are much smaller and easier to install than cooling towers.

### 7.4 Observations

**Changing Attitudes:**

Users of cooling towers and fin fans are willing to invest dollars to improve their fan monitoring systems. There are several reasons for this, some of which have been discussed earlier. The main reasons are:

- The current solution does not work since unanticipated failures continue to occur.
- Users are becoming more knowledgeable in vibration measurements, and demand better performance.
- The pressure to reduce operating and maintenance costs makes false trips and missed trips intolerable. Reliability is of utmost importance.
- Downsizing is reducing maintenance staff headcount, increasing the chance that cooling towers and fin fans will be neglected.
- Users are realizing the potential danger a fan failure could pose to humans, thus increasing the awareness of the need for a warning of impending failure.