VTBNet –Low Cost and Practical approach to Vibration Monitoring for WasteWater Treatment Plants

A wastewater treatment plant is designed to remove biological or chemical waste products from water, thereby permitting the treated water to be used for other purposes while complying with environmental requirements.

These plants typically rely on maintenance personnel to keep the machinery running. However, periodic machine monitoring with vibration data collectors is not the best way to evaluate plant equipment because critical vibration information can be missed.

It is ultimately up to the owners and operators of a wastewater treatment plant to decide what levels of vibration monitoring is adequate for protecting and monitoring their plant assets. The table below is intended to point out commonly used vibration devices and their application disadvantages for the protection of plant equipment. The table is for informational purposes only, and one should evaluate your specific application as required.

Permanent Vibration Devices Commonly used for Plant Equipment Asset Protection	
Vibration Device	**Application Considerations**
Mechanical Vibration Switches	Manufacturers generally do not list the accuracy or repeatability of their mechanical vibration device**. It is important to note that this device has no useful signal outputs, no trending capabilities, no analysis capabilities for condition monitoring, and no advance warnings for a deteriorating machine.** In 1995, API 618, 4th edition, the standard for reciprocating compressors wrote that mechanical vibration switches are "unacceptable" to be specified as a continuous vibration device. To this date, due to the unreliability of the mechanical vibration switch, they are not specified in any American standard publication for any type of process equipment or machinery. Mechanical switches, in the simplest sense, are basically inertia activated devices that require large changes in g forces to trip. There are many wastewater treatment plant processes that operate at 35 RPM or less – these slow speeds will not create large enough changes in g forces to trip a mechanical vibration switch set to one g or higher. Note that for trip setting under 0.5 g, the mechanical switch is unstable and will trip due to mild bursts of wind or the closing of nearby plant doors. The "normally closed" (NC) and "normally open" (NO) contacts on the internal microswitch (SPDT) can become

	erratic during the mechanical resonance (high g levels) encountered during the start-up of a large motor and pump set. Consider an imbalance condition and mechanical resonance occurring at the same time. There is already the inability of the mechanical switch to detect low-level g forces; couple this problem with excessive g force levels that disable the microswitch during the component or system mechanical resonance. Operators prefer to test the functionality of the mechanical switch while it is still mounted on the machine. The typical approach is to impact the machine casing at, or around, the location of the switch with a hammer. The operator then repeats this procedure until the switch trips. Unfortunately, repeating this test over time can dislodge the internal adjustable spring, armature, or some mechanical part or component. The switch may work partially, but the switch is basically unreliable. Also, internal mechanical components may have become corroded due to ingress of moisture or ambient corrosives, which could cause the switch to fail. Therefore, with corroded internal components, lowering the g level setpoint for test purposes will not cause your mechanical switch to trip. **There are many non-functional mechanical switches in the field, and wastewater treatment plants are not properly protected against excessive machine forces.**
Two-Wire Loop Powered Vibration Transmitters	Once installed, the performance of this device can be verified, but are unable to be recalibrated in the field or factory. This electronic device is simply a pass/fail, disposable unit. Further, two-wire loop powered devices are especially vulnerable to direct two-way radio interference created in many remote process plants. There are no fault protocols for problem transmitters, so, discrete fault level cannot be set to 0mA, DC. This configuration is not suitable for control rooms that require a 0ma, DC level for a fault indication.
Electronic Vibration Switch with Built-in Sensor	Internal electronic components have a limited temperature range which restricts an electronic vibration switch from hot machine casing temperatures (eg. diesel engines). Built-in sensors may have a wide band range, but the actual system frequency response is controlled by the signal conditioning electronics. This affects the ability to accurately measure low speed vibration measurements lower than 120 RPM (2 Hz), which is found in low-speed process equipment. Further, for displacement measurements (mils, pk-pk), there are additional measurement errors created during signal conditioning by double integrating the vibration signal from acceleration to displacement at speeds below 600 RPM (10 Hz). A vibration switch configured with a fixed start-up delay or self-test functionality of long duration will not detect an imbalance condition that could cause damage to the air cooler heat exchanger. Many manufacturers assemble their product without encapsulating the internal electronics with epoxy or a resin-based coating. The main purpose of the epoxy or coating is to protect the electronics from moisture and corrosive environments, but there is the added benefit of securing the electronic and mechanical components from the destructive physical forces encountered during the product's life cycle.

Motor and Pump Sets - Vibration Monitoring

A pump is a device that moves a gas or liquid from one area to another. This can be done by accelerating the liquid using centrifugal forces, or by grabbing a certain amount of liquid and physically pushing it towards where it needs to go (by positive displacement pumps). Pumps are perhaps the most widely used mechanical devices and they are used extensively in waste water treatment plant applications. Commonly used centrifugal pump types are overhung pumps, vertical pumps, and multi-stage split case pumps. Less costly positive displacement pumps (typically used for uncritical applications) are reciprocating pumps, lobe pumps, helical pumps, screw pumps, and the gear pumps.

In the past, operators used hand-held data collection devices to walk to each machine and gather vibration data. The motor, pump, and blowers are possibly accessible, but there are many equipment assets to measure and the procedure is time-consuming and tedious. Additionally, given that machines are not monitored 24/7, this method is much less capable of detecting impeding roller bearing or

conveyor failures. Today, with the latest innovations from Machine Saver, our technology can be coupled with a practical approach to reliably monitor, analyze, and detect vibration anomalies on motor and pump sets with a minimum of two digital transmitters. These digital transmitters offer integral cable assemblies, minimal instrumentation wiring, and an industrial computer configured with vibration monitoring software. Also – any instrumentation wiring can be avoided by simply using the wireless option.

Advantages of Wireless Vibration Monitoring

Wireless vibration monitoring can provide early alarms for remote locations so that effective maintenance measures can be taken, and so machine reliability can be improved. Machine Saver's VTB-RS485 three-axis sensor utilizes the latest technology and innovation to monitor and protect machinery remotely – while decreasing labor and maintenance cost and time. Online vibration analysis can be obtained at any time from any location, thereby minimizing installation related costs.

Trended overall vibration levels can be kept on a company's virtual server for trending capabilities and future reference. Early alarm thresholds can be set to provide sufficient time for plant management to purchase required parts and schedule tower downtime. Furthermore, the accessibility of many digital protocols, and the simplicity of wireless capability, gives users flexibility and ease in using this vibration monitoring system with any third-party wireless transmitter and receiver system.

VTB-Sensor Capabilities

The VTB-Sensor is three-axis (X,Y, and Z) digital and temperature transmitter which can detect a multitude of rotational and structural problems, such as imbalance, misalignment, a bent shaft, and mechanical looseness. Additionally, this sensor can detect rolling element bearing problems in their early stages. The sensor can simultaneously detect in the three measurement planes mentioned above, along with all three vibration measurands: acceleration, velocity, and displacement. The embedded temperature sensor has a service range of -40°F to 221°F (-40°C to 105°C). By integrating three-axis vibration detection and temperature into one digital transmitter, one transmitter can take the place of *seven* sensors. Figure 1 illustrates the vibration measurement planes detected by the VTB-Sensor.

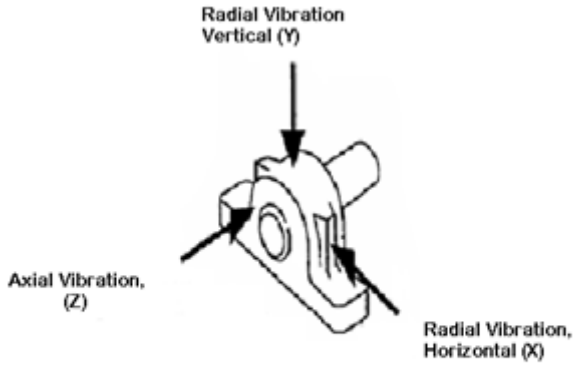

Figure 1., Roller Bearing - Shaft Vibration Measurement Planes

VTB-Com System

VTB-Com is an industrial communications system designed to interface and monitor the digital signals coming from the VTB-Sensor. The VTB-Com can log digital signals from several VTB-Sensors, and can communicate the data to other computers using a variety of digital communications, such as

- Ethernet
- USB
- GSM
- Wireless systems

VTB-Com has four independent CAN bus channels that can each power and communicate up to twenty-four daisy-chained VTB-Sensors. This is done utilizing a CAN bus cable with a range of 132 feet (40 meters). **In hazardous locations, CAN bus ports are limited to twenty-four VTB-Sensors, and the total cable distance is limited.**

VTBNet Protection System and Condition Machine Monitoring

By using the VTB-Sensor and VTB-Com system together, VTBNet becomes a cost-effective vibration monitoring system that can be easily installed to monitor and protect fin fan assets. This permits users to utilize a By integrating VTB-Sensor, VTB-Com, sensor computer, and the CBMvision® machine condition monitoring software, an enhanced VTB Net can take a snapshot of the dynamic signals and to upload the dynamic vibration and temperature data to the cloud where its is automatically analyzed to detect trends and predict future problems with WWTP equipment assets.

More plant maintenance departments, instrumentation personnel and reliability managers are adding VTB-Sensor to their machines. It no longer requires a capital expenditure since you can add the VTB-Sensors one at a time and after the first VTBNet is installed you only have to run the communication link back to the closest VTB sensor. With so many digital protocols available on the VTBNet system, it is also

very easy to make this VTBNet system all wireless with any third party wireless transmitter and receiver system so it lends itself well to integration with the very latest technology.

VTB Net system advantages: (1) Low cost; (2) Easy installation; (3) Less parts to fail; (4) Less wire to install; (5) wireless option; (5) Smaller footprint; (6) More information from one sensor; (7) Lower cost on the computer I/O module; (8) Unique universal sensor mounting feature;(9) Dynamic capture and signal analysis;(10) Zone 1 / Div. 2 certified

VTB-COM

VTB Sensor

VTBNet Product Application

VTB Sensors with an integrated cable assembly designed for wet, submerged, and corrosive environments can be used to detect and monitor the vibration levels of the motors, pumps, compressors, and blowers. By measuring vibration continuously, machine degradation can be monitored and impending failures can be prevented to avoid unscheduled shutdowns.

For example: on a horizontal motor and centrifugal pump set, the practical approach is to permanently mount two (2) VTB-Sensors in a radial and horizontal direction perpendicular to the shaft centerline. Refer to Figure 2. Note the placement of the VTB-Sensor is located near the suction inlet for optimal cavitation measurements, but, suitable to detect roller bearing defects. **To provide a best practice**

mounting procedure for the VTB-Sensors, our team needs to know the drive & driver components, and the existing environmental conditions.

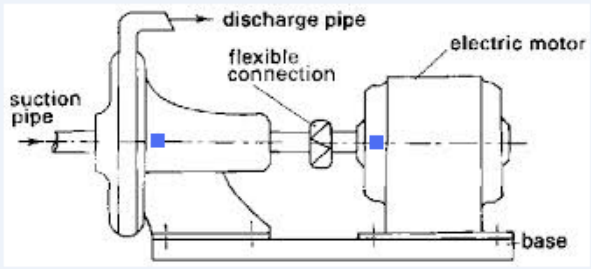

Figure 2., Typical Mounting Locations for VTB-Sensor, 3-Axis Digital Transmitter on a Motor/Pump Set

Figure 3., Typical Mounting Locations for VTB-Sensor, Motor/Overhung Pump

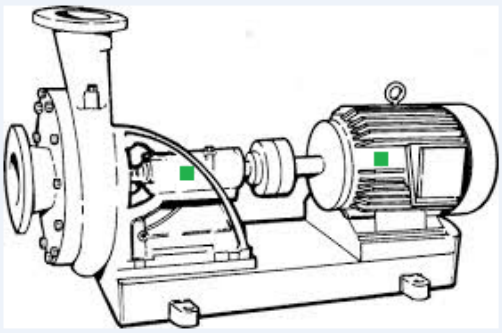

Figure 4., Typical Mounting Locations for VTB-Sensor, Vertical Motor/Pump Set

Practical Vibration Monitoring Guidelines

Machine Saver, Inc., is pleased to provide a new technology that can be coupled to a best practice procedure that can be used for all your process plant vibration monitoring.

In the past, a portable vibration meter was used to determine the highest vibration plane on a machine. Then the permanent vibration sensors were placed on the vertical or horizontal axis that was most sensitive to a machine's vibrations.

VTB-Sensor, 3 –Axis Digital Transmitter takes the guess work out of the mounting location and can simultaneously detect in three measurement planes (X,Y, and Z) and in two vibration measurand-acceleration and velocity. The embedded temperature sensor has a service range of -40°F to 221°F (-40°C to 105°C). By integrating 3-axis vibration detection and temperature into one digital transmitter, one transmitter can take the place of seven sensors.

For most WWTP applications, mount one (1) VTB-Sensor on machine driver (inboard) and one (1) VTB-Sensor on the driven machine (inboard) per the following guidelines:

1) Decide to install what is required instead of installing what is simple or convenient. As a protection device, a mechanical switch is unreliable and has no useful signal outputs, no trending capabilities, no analysis capabilities for condition monitoring, and no advance warnings for a deteriorating machine. Some companies have a machine condition monitoring system and they use a mechanical switch for machine protection in case there is a brown out period or a power outage. VTBNet will accurately perform as a condition machine monitor and for machine protection by utilizing a separately priced external relay board to shutdown you machine asset. To insure continuous vibration monitoring and protection, simply utilize an Uninterruptible Power Supply (UPS) set to a nominal +24 VDC to power the VTB-Com, Sensor Communication Computer and daisy chained VTB-Sensors.

2) Obtain technical expertise from Machine Savers, Inc., with applications involving the use of band pass filters for the diagnosis of machine vibration levels; or, the use of vibration devices in a hazardous locations or corrosive environments, e.g., sour gas, salt-spray, high or low pH levels.

3) Verify that the machine rotating shafts are supported by rolling element bearings. VTB-Sensor is a digital sensor that was designed to detect and monitor low frequency vibrations, e.g., imbalance, misalignment, high frequency roller bearing condition, and temperature. Mount the VTB-Sensor in the radial position at or around the roller bearing cap. Do not mount the digital transmitter on a flimsy bracket, or the sheet metal part of the machine.

4) Vertical pumps and air compressors may have a mix of sleeve bearings and roller bearings. Simply mount the VTB-Sensor as close as possible to the roller bearings.

5) For small horizontal pumps or compressors with sleeve bearings, mount one (1) VTB-Sensor per machine in the radial position perpendicular to the rotating shaft. Since the vibrations are attenuated by the sleeve bearing, trend the overall vibration levels continuously and accordingly lower your set point trip levels. Remember for each machine you are trending one temperature level and nine vibration levels. Therefore, overtime, you may have a measurement plane that a very low vibration level, but the other measurement planes will indicate changes in vibration levels due to machine's low frequency vibration levels, e.g., imbalance or misalignment.

6) Review the machine's maintenance records. Mount the VTB-Sensor as close as possible to source of vibration. Based on the records, this area will have the most wear and is most likely to have problems.

7) On less expensive motors, blowers, positive displacement pumps, fans, compressors, consider a budgetary approach and mount at least one VTB-Sensor per set. Place the VTB-Sensor where it will monitor the most- on the inboard section of the driven machine, e.g., screw pump, compressor, or blower. This area will have the most wear, and is most likely to have problems.

8) Understand what trending the overall vibration levels means. Overall vibration is the total vibration energy measured within a wide frequency range. Overtime, a higher than normal overall vibration level indicates that some force is causing the machine to vibrate more. As you increase the speed of the machine that vibration energy becomes more destructive. The enhanced overall vibration levels provided by VTB-Sensor will indicate continuously what your overall vibration levels are and this provides time for operators to create a standard baseline vibration level for each machine asset. Once the baseline vibration levels are reached, you can plan and schedule an inspection of the machine components and the roller bearings.

9) VTB-Com, the sensor interface computer, can be mounted inside a NEMA 4X, IP65, agency approved enclosure with a built-in window. The enclosure must be resistant to ambient air corrosives, e.g., chemically treated water spray, and chlorine. If the machine is located outdoors, shelter the enclosure from direct sunlight and verify that the input/output glands, strain reliefs, and instrumentation wiring are rated for the specific applicable.

10) The recommended wiring format is 18 AWG /4 conductors, 120 ohms, shielded twisted pair cable that is maintained via the shielded yellow T-port connectors which allows for multiple VTB-Sensors to be wired together in sequence, e.g., daisy chain.

11) Vibration measurement errors and false alarms often can be traced to installation problems involving ground-loop noise. Ground loops can be avoided by mounting the VTB-Sensor as required and utilizing the shielded connection when fastening other VTB-Sensors. The shield connection on the VTB-Com power connector must be used to maintain shielded continuity through-out the installation wiring.

Suggested Vibration Trip Levels

You can monitor the vibration levels in three simultaneous planes (X,Y, and Z) and in three vibration measurands, but, the velocity measurand is best for speeds of 600 RPM (10 Hz) or greater. This is because the velocity (ips) measurement is constant over a wide range of speeds and frequencies. For machine protection, the typical vibration trip levels are shown in the chart below for different types of equipment commonly used in WWTPs. **To convert from pk to rms, simply multiply the ips, pk by 0.707 to obtain ips, rms.**

These suggested trip levels are starting points and the recommendations provided by the equipment manufacture should be followed. Preliminary references for suggested vibration limits are the Vibration Institute, Hydraulic Institute (pumps), ISO-2372, and ISO-10816-3.

Typical Vibration Trip Levels - Velocity

Type of Machinery	Electrical Motors Gear Boxes	Conveyors	Centrifugal Pumps	Centrifugal Compressors	Gear Pumps	Fans/Blowers	Reciprocating Pumps & Compressors
Typical Vibration Trip Level (ips,pk)	0.1 to 0.3	0.3 to 0.5	0.1 to 0.3	0.2 to 0.4	0.1 to 0.3	0.2 to 0.4	0.5 to 0.7

Overall Vibration Levels

The easiest way to obtain the base line vibration for your machine is to simply measure the vibration levels over a wide frequency range. The VTB-Sensor must be mounted on the bearing housing or as close as possible to the roller bearings. The vibration measurements can be trended over time and compared with know levels of vibration or alarm and shutdown set points can be set due to changes in the condition of the machine.

Analysis of trended vibration levels combined with experience and familiarity with the machine is essential to monitor the status of your machine. In addition to vibration measurements, temperature is an important parameter for providing information on bearing stress and machine operating conditions. Analysis of vibration and temperature together provides condition monitoring where the condition of the machine is monitored for early signs of deterioration. The table below provides some common machine vibration and temperature faults.

WWTP - Common Machine Vibration and Temperature Faults

Machine Component/Fault	Frequency Order	Measurement Plane	Vibration Measurand	Comments
Belt Drive Pulley System/Worn or Improper Belt tensions	1X,2X,3X,4X RPM of Belt	Radial	Velocity, in/sec, rms	Belt frequencies are below the RPM of either the motor or the driven machine. When they are worn, loose or mismatched, they can cause dominant vibration peaks at 2X, 3X, and 4X RPM of Belt. Small amplitudes of axial vibration can occur.
Belt Drive Pulley System/Misaligned Pulley/Eccentric Pulley/Belt Resonance	1X,2X RPM of Belt	Axial	Velocity, in/sec, rms	Excessive driver pulley and driven sprocket misalignment or extreme sheave wear may appear as imbalance. Three types of pulley misalignment: offset, angular, and twisted.
Belt Drive Pulley System/ Eccentric Pulley/Belt Resonance	1X RPM of Belt	Radial	Velocity, in/sec, rms	Eccentric Pulleys: The geometric center does not coincide with the rotating center of the pulley and the vibration may be higher in the directions of the belts. Belt resonance may coincide with either the driver pulley or driven sprocket RPM.
Motor/Imbalance	1X, 2X Motor RPM	Radial	Velocity, in/sec, rms	Small amplitudes of axial vibration can occur. Imbalance can be intensified by mechanical resonance. 1X Motor RPM vibration can also be caused by Soft Foot.
Motor/Bent Shaft	1X, 2X Motor RPM	Axial	Velocity, in/sec, rms	Bent shaft can cause roller bearings misalignment.
Motor/Mechanical Looseness	1/2X,1/3X,1/4X,1X,2X, Motor RPM	Radial (Vertical)	Velocity, in/sec, rms	There may be some vibration levels on the horizontal plane, but, the amplitudes will be highest near the mechanical fault. Excessive coupling wear can lead to mechanical looseness.
Motor/Rotor Bar and Stator Defects	1X,2X,3XMotor RPM 2X Line Frequency	Radial	Velocity, in/sec, rms	Rotor Bar Passing Frequency (F_{RBPF}) = Motor RPM X No. of Rotor Bars. Broken rotor bars are common faults that cause electrical imbalance. Small amplitudes of axial vibration can occur.
Motor/Shaft/Coupling Misalignment	1X,2X,3X 4X,5X,6X, Low Level Harmonics	Axial and/or Radial	Velocity, in/sec, rms	Shaft/Coupling Misalignment may involve both Angular (Axial) and Parallel Offset (Radial) Misalignment. Misalignment can occur under the following conditions: 1. Machine alignment and installations errors; 2. worn roller bearings; 3. settling of bases, foundations, and tower structure; 4. shift of relative position of machines after installation.
Motor/Resonance	Less Than, Equal to, or Greater Than Motor/Fan RPM	Radial, Axial	Velocity, in/sec, rms	Resonance appears when a source frequency coincides with the natural frequency of the support structure, base foundation, piping, or mechanical component, e.g., rotor, gearbox, or belt driven systems. Resonance can be confirmed by verifying that a small change in speed causes the 1X Motor RPM vibration levels to change greatly.
				Cavitation can be caused by improper supply of process fluid. Mount the VTB-Sensor near the pump inlet (suction) area to monitor for cavitation. An impeller vane filled with foreign material or impeller erosion can lead to machine imbalance or misalignment.

Centrifugal Pump	Number of Impeller Vanes X RPM	Radial	Velocity, in/sec, rms	Turbulence – is induced when the fluid is forced to make abrupt changes in direction such as sharp bends in discharge piping. The dominant peaks occur at less than 1X RPM. Recirculation - may occur when the fluid flow of the pump is reduced by throttling the discharge valve. Mount the VTB-Sensor near the pump discharge area to monitor for this condition that can be caused by excessive throttling.
Rolling Bearing Defects with Visible Damage to the Bearings	1X to 10X 10X to 50X	Radial	Velocity, in/sec, rms	The vibration frequencies begin to manifest themselves in the 5 KHz to 15 KHz range. As the roller bearing wear increases and approaches failure, there will be an increase in overall vibration levels in the 500 Hz to 2500 Hz range. For bearing defects within 1X to 50X Machine RPM, s**chedule a machine repair as soon as possible and inspect the roller bearings. If required, replace the roller bearings and find the fault(s) causing the bearing defects,** e.g., imbalance, misalignment, improper bearing loads, excessive bearing temperature, contaminated lubrication, or, insufficient bearing lubrication.
Gearbox/Mechanical Looseness	1X,2X Fan RPM	Radial (Vertical)	Velocity, in/sec, rms	Aerators, agitators, and scrapers are generally connected to a gearbox. There may be some vibration levels on the horizontal plane, but, the amplitudes will be highest near the mechanical fault.
Gearbox/Worn or Broken Gear Teeth	GMF X 3.25	Radial	Velocity, in/sec, rms	Gear Mesh Frequency (GMF) = [No. of $Teeth_{Gear}$ X RPM_{Gear}]or [No. of $Teeth_{Pinion}$ X RPM_{Pinion}] Shaft misalignment can cause high loads on the input gear, which causes misaligned gears and can lead to worn or broken gear teeth.
AC Motor Windings and Roller Bearings Gearbox Roller Bearings (Overheating)	1X Motor RPM	Radial Axial	Velocity, in/sec, rms	VTB-Sensor can detect and monitor for excessive machine heat that causes rapid deterioration of motor winding insulation and roller bearing damage that can lead to AC motor failure. Overheating in the AC motor bearings is generally lubricant-related. Normal motor bearing operating temperatures range from 140°F (60°C) to 160°F (71°C). Roller bearings in gear drives normally operate at 160° (71°C)-180°F (82°C). Overheating in motors and gearboxes can be caused by increased bearing loads due to machine imbalance or misalignment. Contamination of the roller bearings lubricant by solid particles, water, and other fluids can reduce the life of the bearings. Improper lubrication generally causes overheating or excessive wear in the roller bearings. These conditions can result from insufficient or excessive lubrication, improper lubricants, e.g., viscosity is the load bearing component of the lubricant. Too thin, then the bearings cannot properly carry the load; and too thick, then the amount of friction will generate heat.

Conclusion

With a combination of best practice techniques, correct setting of vibration and temperature alarm settings, and interpretation of vibration spectra, your WWTP equipment assets can be protected against rising motor, fan, or blower vibration and bearing temperatures. These machine faults can cause complete machine failure which cause plant processes to stop running. Vibration monitoring and protection can detect developing problems like roller bearing wear, machine operation at system mechanical resonance, and mechanical support issues.

This technical note has practical suggestions to assist you in your vibration monitoring and protection application. While our product will not detect every vibration and temperature fault, we understand what others don't- that every application requires essential machinery vibration expertise and involvement so that we can provide a customer focused solution to your vibration monitoring requirements. We want to support you with a reliable vibration and temperature product that successfully and consistently detects, monitors, analyzes, and protects your equipment investment. Let us know about your application by consulting with the Machine Saver team at service@machinesaver.net Our team can provide vibration monitoring solutions and benefits for your present application and extend their vibration expertise and new technology to your entire balance of plant. Product and application information is available at www.machinesaver.com

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