

## **VTBNet – Low-Cost, Practical Approach to Vibration Monitoring of Conveyor Belt Systems**



A conveyor belt is the carrying medium of a belt conveyor system. A belt conveyor system consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium - the conveyor belt - that rotates about them.

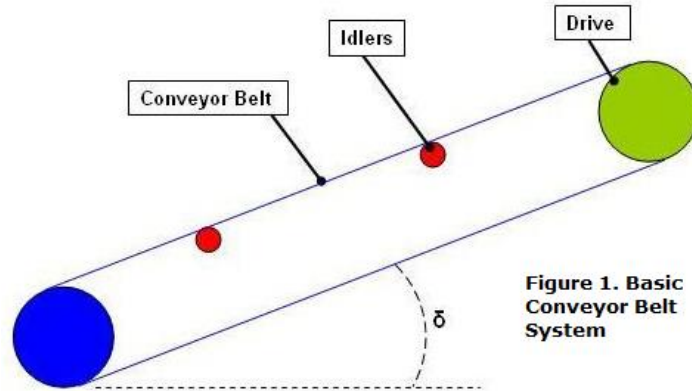
One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley. See figure 1 below.

There are two main industrial classes of belt conveyors:

1. General material handling (i.e., moving boxes along inside a factory)
2. Bulk material handling or transportation used to move large volumes of material goods (i.e., coal, ore, lignite, grain, salt, sand, and other resources)

The use of steel-belt conveyors has spread throughout the processing industries. Applications of steel-belt conveyors include cooling/solidification, drying, pressing, freezing, baking, and materials conveying.

A belt conveyor is an important system component of production in many processing and mining industries. Their failure can cause expensive repairs and reduced loads during peak demand. The efficiency and reliability of this system is an important concern to all operators.



**Figure 1. Basic Conveyor Belt System**

It is ultimately up to the plant owner to decide what levels of vibration monitoring are adequate for protecting and monitoring their conveyor belt system.

The table below is intended to point out commonly used vibration devices and their application disadvantages for the protection of the drive pulley and the idler pulley. The table is for informational purposes only. The specific empirical evaluation of your product and application is recommended.

Permanent Vibration Devices Used for Industrial Conveyor Belt Systems	
Vibration Device	Application Considerations
<b>Mechanical Vibration Switches</b>	<p>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.</p> <p>Mechanical switches which are basically inertia activated devices that require large changes in g forces to trip. There are process equipment operated at low RPMs and they will not create large changes in g forces to trip a mechanical vibration switch set to 1 g or greater. 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.</p> <p>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 process equipment start-up.</p> <p>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 act 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 not reliable. Another possible reason that the switch did not trip initially to the hammer impact is because the internal mechanical components may have become corroded due to ingress of moisture or corrosives. Therefore, with corroded internal components, lowering the g level setpoint for test purposes will not allow your mechanical switch to trip.</p> <p><b>Basically, there are many non-functional mechanical switches in the field and your process equipment investments are not properly protected against excessive machine forces.</b></p> <p>Mean Time Between Failures (MTBF) numbers are not listed on product data sheets or product manual.</p>
<b>Two-Wire Loop Powered Vibration Transmitters</b>	<p>Once installed the performance of this device can be verified, but, in the field or at the factory, they cannot be recalibrated. This electronic device is simply a pass/fail and disposable unit. Further, two-wire loop powered devices are especially vulnerable to direct two-way radio interference used in many remote plant facilities.</p> <p>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.</p>

**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, e.g., diesel engine.

Built-in sensor 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 less than 120 RPM (2 Hz), e.g., low speed fan. Further, for displacement measurements (mils, pk-pk), there is the added measurement errors created during signal conditioning by double integrating the vibration signal from acceleration to displacement at speeds below 600 RPM (10 Hz).

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 harm to personnel and damage to nearby equipment.

Many manufacturers assemble their product without encapsulating the internal electronics with epoxy or alternatively, by using resin based conformal coated printed circuit boards. While the real intent for the epoxy or coating is to protect the electronics from moisture and corrosive environments; there is the added benefit of securing the electronic and mechanical components from the destructive forces encountered during the product's life cycle.

## Conveyor Belt Drives - Vibration Monitoring

Within the product processing and mining industries, it is common for machinery such as pumps, fans, screens, crushers, and conveyor belt systems to be running around the clock. The rotating components must be continuously monitored to warn of low frequency imbalance, misalignment, roller bearing wear, and impending bearing failure.

As these machines are frequently installed in difficult-to-access areas, it's dangerous work for operators to climb up on the conveyor structures to take vibration measurements.

Today, with the latest innovations from Machine Saver, Inc., a new technology can be coupled with a practical approach to reliably detect, monitor, analyze, and protect conveyor belt systems. This is done with digital transmitters formed with integral cable assemblies, sensor-to-sensor instrumentation wiring, and an industrial sensor computer. Instrumentation wiring from the sensor interface computer to the control room 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 measures and machine reliability can be improved. One advantage of wireless vibration monitoring is that it uses the latest technologies from Machine Saver, Inc., to move vibration and temperature data rather than people. Online vibration analysis can be obtained at any time from any location, thereby minimizing installation related costs. Plant personnel can avoid climbing on top of the air cooler fans to take vibration measurements and making trips to hazardous plant locations.

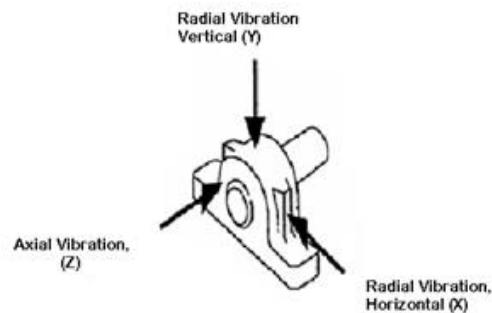
Trended overall vibration levels can be kept on the cloud for future reference. Early alarms can be set up to provide sufficient time for management to plan for the scheduling and purchasing of parts and tower downtime. Another advantage is the accessibility of many digital protocols and the ease to make our vibration monitoring system all wireless with any third party wireless transmitter and receiver system.

## VTB-TriVibe

VTB-TriVibe is a three-axis (X, Y, Z) digital and temperature transmitter with an integral 18-foot (six-meter) cable which can detect rotational and structural problems (low frequency) (i.e., imbalance, misalignment, bent shaft, and mechanical looseness) and rolling element bearing problems (high frequency) in their early stages.

The sensor can simultaneously detect in three measurement planes (X, Y, Z) and in 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 2 illustrates the vibration measurement planes detected by VTB-TriVibe.



**Figure 2., Roller Bearing - Shaft  
Measurent Planes**

## Machine Gate

Machine Gate is an industrial communications computer designed to interface and monitor the digital signals coming from VTB-TriVibe. Machine Gate can log the digital signals from several VTB-TriVibes and communicate the data to other computers using a variety of digital communications such as:

- Ethernet
- USB
- GSM
- Wireless Systems

Machine Gate has four independent CAN bus ports that can each power and communicate with up to 24 daisy-chained VTB Sensors – for a total of 96 VTB Sensors with a cable range of 329 feet (100 meters). **This is in non-hazardous locations only. In hazardous locations, the entire CAN bus ports are limited to 24 VTB-TriVibes and the total cable distance is limited.**

## **VTBNet – Protection System and Condition Machine Monitoring**

By using VTB-TriVibe and Machine Gate, sensor computer together, VTBNet becomes a cost-effective online, vibration system that can be easily installed to detect and protect fin fan assets. By integrating VTB-TriVibe, Machine Gate, sensor interface computer, and the CBMvision® machine condition monitoring software, an enhanced VTBNet 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 the cooling tower

More plant maintenance departments, instrumentation personnel and reliability managers are adding VTB-TriVibe to their machines. It no longer requires a capital expenditure since you can add the VTB-TriVibes one at a time. After the first VTBNet is installed, you only have to run the communication link back to the closest VTB-TriVibe.

With so many digital protocols available on the VTBNet system, it's 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:**

- Low cost
- Easy installation
- Less parts to fail
- Less wire to install
- Wireless option
- Smaller footprint
- More information from one sensor
- Lower cost on the computer I/O module
- Unique universal sensor mounting feature
- Dynamic capture and signal analysis
- Zone 1 / Div. 2 certified



Machine Gate



VTB-TriVibe

### VTBNet Product Application

VTB-TriVibe, with an integrated cable assembly designed for wet and corrosive environments, can be used to detect and monitor the vibration levels of the conveyor belt systems (motor, coupler, gearbox, drive pulley, and idler pulley). See figure 2 below.

By measuring vibration continuously, machine degradation can be monitored and impending failures can be prevented to avoid unscheduled shutdowns.

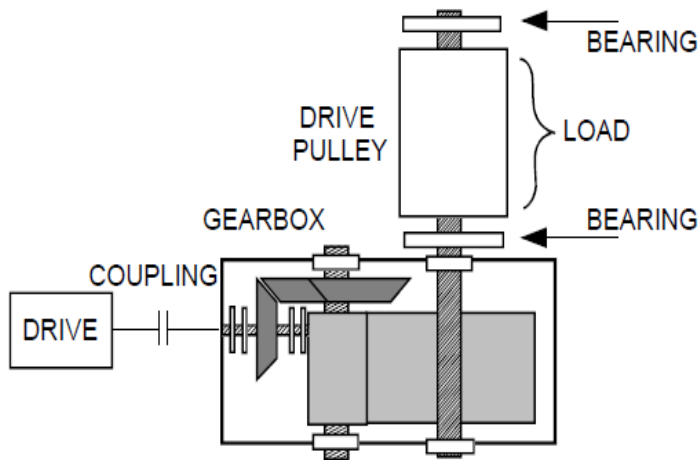
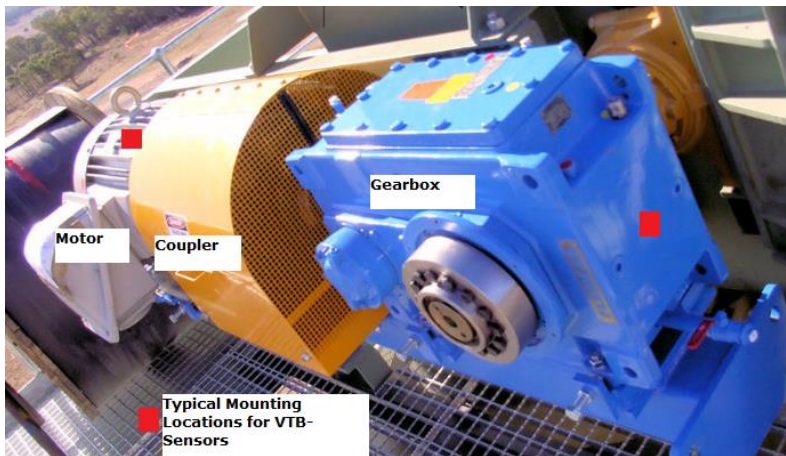


Figure 2. Conveyor Belt System - Motor/Gearbox/Drive Pulley



## VTB-TriVibe Mounting Locations



### Product Processing and Mining Plants – Application Considerations

- 1) Access to components of a conveyor belt system may be difficult as the motor, gearbox, and roller bearings can be integrated into a drum which allows physical contact only to the pulley drive. Once the vibration sensors are placed on the conveyor belt system, there is the added concern of the product falling (iron ore) on top of the digital sensor and cable assemblies. Therefore, it is important that the VTB-TriVibes are mounted in a way to minimize interaction with the moving product.
- 2) The drive unit consists of the following: electric motor, damping coupler, gearbox and the coupler that connects the output shaft to the drive pulley. The frequency of component failures in this group is from the highest to the lowest – gearbox, pulleys, motor, and couplers respectively. As illustrated above, two (2) VTB-TriVibes are recommended to monitor the gearbox and the motor. At a minimal, you can use one (1) VTB-TriVibe to monitor the gearbox for gear teeth problems and roller bearing faults.
- 3) The VTB-TriVibe has a built-in temperature sensor that can be used to detect an overheating motor, coupler, gearbox and drive pulley.
- 4) Roller bearing failures of large pulleys under conveyor belt tension can cause considerable damage to the drive unit or the conveyor belt structure. Overheated roller bearings can also start fires, fueled by dust, grease or paint. The VTB-TriVibe, three-axis digital transmitter also has a built-in temperature sensor to monitor the overheating of roller bearings.
- 5) Although idler pulleys are not as critical as drive pulleys, the roller bearings in the idler pulleys can overheat and become a fire hazard. It is normal practice for conveyor belts to be inspected on a regular basis by operators who visually check and use a microphone device to listen for idler pulley

problems. Recently, operators have successfully measured the surface temperature of idler pulleys from a safe distance.

- 6) AC motors can fail and shutdown due to excessive bearing temperature or roller bearing defects. While many AC motors incorporate temperature sensors into the motor windings, the VTB-TriVibe digital transmitter has a built-in temperature sensor to provide additional over temperature protection to prevent AC motor damage and subsequent failure.
- 7) Obtain technical expertise from Machine Saver, Inc., with applications involving the use of band pass filters for the diagnosis of machine vibration levels, or the use of vibration devices in hazardous locations, underground mining, or corrosive environments (i.e., sour gas, salt-spray, high or low pH levels).
- 8) Verify that the machine rotating shafts are supported by rolling element bearings. VTB-TriVibe 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-TriVibe 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. The integral cable should be clamped to the body of the sensor with a cable tie to prevent strain and excessive movement of the cable as both these could produce false signals. The integral cable should also be fixed at suitable intervals to cable trays or other suitable supports.
- 9) A mining plant is one of the harshest environments where sensors are to be installed. In order to protect VTB-TriVibe's integral cable, we recommend using stainless steel armored braiding or equivalent.
- 10) Within the mining industry, there may be instances where the sensors are used in potentially explosive gas atmospheres (for example, an underground coal mine [methane atmospheres]). This means any products used in this environment must be ATEX (IECEX) certified for an intrinsically safe area – in this case, specifically Group I (mining).
- 11) Review the machine's maintenance records. Mount the VTB-TriVibe 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. **Recall that downtime on a conveyor belt system is downtime for the mine.**
- 12) Over time, 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-TriVibe 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. **Note: In mining applications, trending of bearing temperatures, CO, CH4 and air flows can prevent potential dangerous conditions such as fires or explosive atmospheres.**



## Suggested Vibration Trip Levels

For machine protection, the typical vibration trip levels are shown in the chart below for different types of equipment commonly used in the processing and mining industries. **To convert from pk to rms, simply take the ips, pk and multiply 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	AC Motors Gearboxes	Conveyors	Gear Centrifugal Pumps	Packaging Machinery	Crushers	Fans/Blowers
Typical Vibration Trip Level (ips, pk)	0.1 to 0.3	0.3 to 0.5	0.1 to 0.3	0.5 to 0.8	0.6 to 0.8	0.2 to 0.4

## Product Processing and Mining Plants – Common Vibration & Temperature Faults

Since excessive vibration is a machine’s reaction to internal and external forces, vibration and temperature monitoring and analysis can be utilized as an indication of the process equipment’s deteriorating condition.

Certain machine faults, such as imbalance, occur at certain frequencies. By determining the frequency of the machine fault and measuring the amplitude of the vibration signal, we can find out what internal or external forces are causing the vibration.

The expected frequency faults in the vibration spectra are called frequency orders (1X, 2X, 70X). They coincide at or around the normal running speed (1/4X, 1/3X, 1/2X, 1X, 2X) or can extend to many times the speed of the running machine (X10, X25, X50). Imbalance or misalignment, for example, occurs at the speed of the rotating shaft (X1) and overheating in motors and right angle speed reducers can be caused by increased bearing loads due to machine imbalance or misalignment.

The damaging forces encountered in Processing and Mining Plants are listed in the table below by each system component. The format is machine component/fault, frequency order, typical measurement plane, and comments. Figure 4 shown below has basic calculations that can be used to approximate the roller bearing faults encountered during the life of the bearing.

<b>Product Processing and Mining Plants – Common Vibration and Temperature Faults</b>				
<b>Machine Component/Fault</b>	<b>Frequency Order</b>	<b>Measurement Plane</b>	<b>Vibration Measurand</b>	<b>Comments</b>
<b>Drive Pulley System/Worn or Improper Belt tensions</b>	1X,2X,3X,4X RPM of Belt	Radial	Velocity, in/sec, rms	Worn, loose, or mismatched belts between the drive pulley and idler pulley can cause dominant vibration peaks at 1X, 2X, 3X, and 4X RPM of Belt. Small amplitudes of axial vibration can occur.
<b>Drive Pulley System/Misaligned Pulley/Eccentric Pulley/Belt Resonance</b>	1X,2X RPM of Belt	Axial	Velocity, in/sec, rms	Excessive driver pulley and driven idler pulley misalignment or extreme sheave wear may appear as imbalance.
<b>Drive Pulley System/Roller Bearings and Shells</b>	1X to 15X Gearbox Output RPM	Radial	Velocity, in/sec, rms	The most frequent failures for pulleys are: bearings and shells
<b>Motor/Imbalance</b>	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.
<b>Motor/Bent Shaft</b>	1X, 2X Motor RPM	Axial	Velocity, in/sec, rms	Bent shaft can cause roller bearings misalignment.
<b>Motor/Mechanical Looseness</b>	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.
<b>Motor/Rotor Bar and Stator Defects</b>	1X,2X,3X Motor 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.
<b>Motor/Shaft/Coupling Misalignment</b>	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. Excessive vibrations can lead to ACHE damage and possible shutdown.
<b>Motor/Resonance</b>	Less Than, Equal to, or Greater Than Motor 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. If the fans are driven by variable frequency drives, the fan speeds may cause resonant frequency vibrations that can affect the air cooler structure. Resonance can be confirmed by verifying that a small change in speed causes the 1X Motor RPM or Blade Pass Frequency vibration levels to change greatly.

Rolling Bearing Defects with Visible Damage to the Bearings	1X to 10X RPM 10X to 50X	Radial	Velocity, in/sec, rms	<p>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.</p> <p>For bearing defects within 1X to 50X Machine RPM, <b>schedule 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</b>, e.g., imbalance, misalignment, improper bearing loads, excessive bearing temperature, contaminated lubrication, or, insufficient bearing lubrication.</p>
<b>Motor and Gearbox/Roller Element Bearings/Overheating</b>	1X Motor RPM 1X Fan RPM	Radial Axial	Velocity, in/sec, rms	<p>Overheating in electric motor bearings is generally lubricant-related. The ball bearings used in most electric motors are pre-greased, shielded ball bearings. Normal motor bearing operating temperatures range from 140°F (60°C) to 160°F (71°C). Normal motor roller 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)</p>
<p><b>Figure 3.</b></p> <p><b>Bearing Faults can be approximated (+/-20%) using the following formulas:</b></p> <p>Outer Race Fault Frequency (BPFO) = 0.45 X Number of Rolling Elements x RPM</p> <p>Inner Race Fault Frequency (BPFI) = 0.55 X Number of Rolling Elements x RPM</p> <p>Rolling Element Fault Frequency (BSF) = 3.5 X RPM</p> <p>Cage Fault Frequency (FTF) = 0.4 X RPM</p>				<p>Overheating in motors and gearboxes can be caused by increased bearing loads due to machine imbalance or misalignment.</p> <p>Overheating can also be caused by bearing misalignment or ball skidding within the bearing.</p> <p>Contamination of the roller bearings lubricant by solid particles, water, and other fluids can reduce the life of the bearings.</p> <p>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. Packing the space around the roller bearings with grease can also cause excessive heat. Avoid the use high pressure grease guns since they may rupture the bearing seals.</p>

## Conclusion

With a combination of best practice techniques, correct setting of vibration and temperature alarm settings, and interpretation of vibration spectra, equipment used in the Processing and Mining Plants can be protected against rising vibration and bearing temperatures (motors, gearboxes, drive and idler pulleys).

This technical note offers practical suggestions to assist you in your vibration monitoring application. While our product will not detect every vibration and temperature fault, we understand what others don't: that every application requires practical 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 process equipment investment.

Tell us more about your application by consulting with the Machine Saver team at [service@machinesaver.net](mailto:service@machinesaver.net). Our team can provide vibration monitoring solutions and benefits for your present application and extend our vibration expertise to your entire balance of plant equipment. Product and application information is available at [www.machinesaver.com](http://www.machinesaver.com).

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