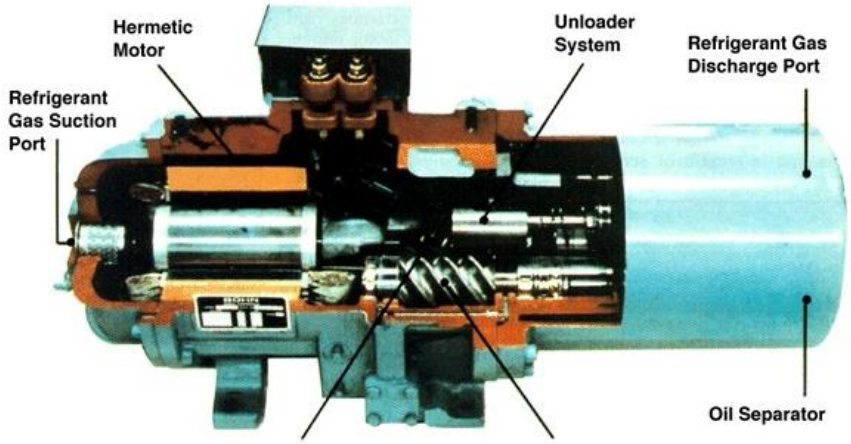
VTBNet – Low Cost and Practical approach for the Vibration Protection and Monitoring of Rotary Screw Compressors



Male and Female Rotor of Rotary Screw Compressor

Rotary screw compressors belong to the machinery group making up rotating positive-displacement compressors. Rotary screw compressors are generally used in higher pressure air and process gas services.

Rotary screw compressors are available in oil-free or oil-flooded construction. Field of application for oil-free machines includes all processes that cannot tolerate contamination of the compressed gas or where the lubricating oil would be contaminated by the gas. Rotary screw compressors are used to compress air, refrigerant, or process gases in the following industries:

- Petrochemical
- Air Separation Plants
- Industrial Refrigeration Plants
- Evaporation Plants
- Mining
- Metallurgical Plants

Rotary screw compressors can be driven by a motor and belt drive system or they can be directly driven by a motor or a motor and gearbox system. Some of the screw compressor systems integrate all the components- motor, belt, and compressor into an enclosure to attenuate the machine noise levels.

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Below are some common systems used to compress air, refrigerate, or process gases:

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Rotary Screw Compressor - Vibration Monitoring

In the past, operators used hand held data collectors for periodic vibration monitoring. The motor and rotary screw compressor sets are accessible, but, process gases are hazardous and there be many equipment assets to measure and the procedure is tedious and less likely able to detect impeding roller bearing or conveyor failures. Today, with the latest innovations from Machine Saver, Inc., a new technology can be coupled to a practical approach to reliably detect, monitor, and protect small motor and rotary compressor sets.

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.

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-Sensor

The VTB- Sensor is a dual 3-axis (X,Y, and Z) digital and temperature transmitter with integral 9 foot (3 meter) cable can detect rotational and structural problems (low frequency), e.g., imbalance, misalignment, bent shaft, and mechanical looseness; and, can detect rolling element bearing problems (high frequency) in their early stages. The sensors can simultaneously detect in three measurement planes (X,Y, and Z) and in two vibration measurands- acceleration or velocity. The embedded temperature sensor has a service range of -40°F to 221°F (-40°C to 105°C). Figure 1., illustrates the vibration measurement planes detected by VTB-Sensor.

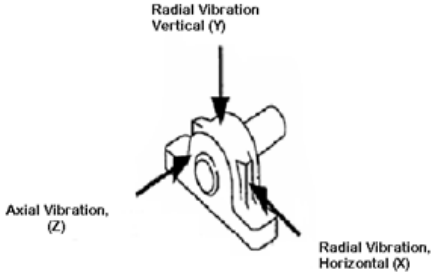

Figure 1., Roller Bearing - Shaft Vibration Measurement Planes

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VTB-COM

VTB-Com is a communications gateway designed to interface and monitor the digital signals coming from VTB-Sensor. The VTB-Com can log the digital signals from several VTB Sensors simultaneously and communicates the data to other computers using a variety of digital media: Ethernet, USB, GSM and wireless systems. In hazardous locations, the VTB-Com has four independent CAN bus ports that together can power and communicate with up to twenty-four (24) daisy-chained VTB-Sensors. In non-hazardous locations the CAN bus ports can work with more VTB-Sensors depending on how much data is captured by each VTB-Sensor.

VTBNet Protection System and/or Condition Machine Monitoring

By using VTB-Sensor and VTB-Com, sensor gateway together, VTBNet becomes a cost-effective online, vibration system that can be easily installed to protect your process equipment assets. By integrating VTBNet with a third party 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 your balance of plant equipment assets.

VTB-COM

VTB-Sensor

VTBNet Product Application

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

For example: on a small horizontal motor and rotary screw compressor set, the practical approach is to permanently mount two (2) VTB Sensors in a horizontal or vertical (radial) direction perpendicular to the shaft centerline as indicated below.

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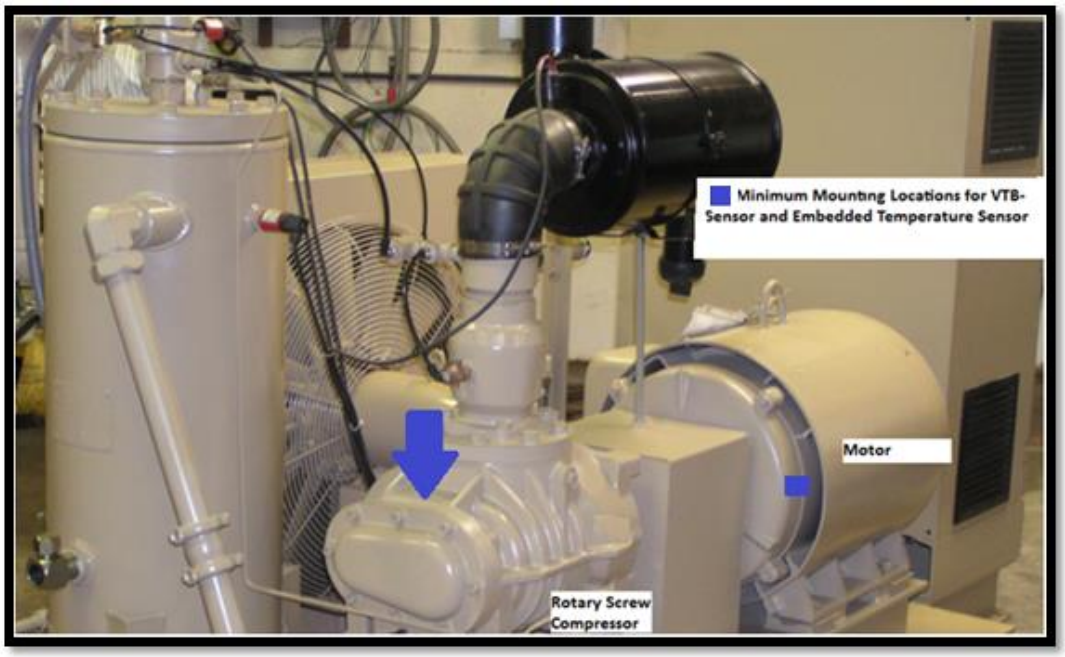

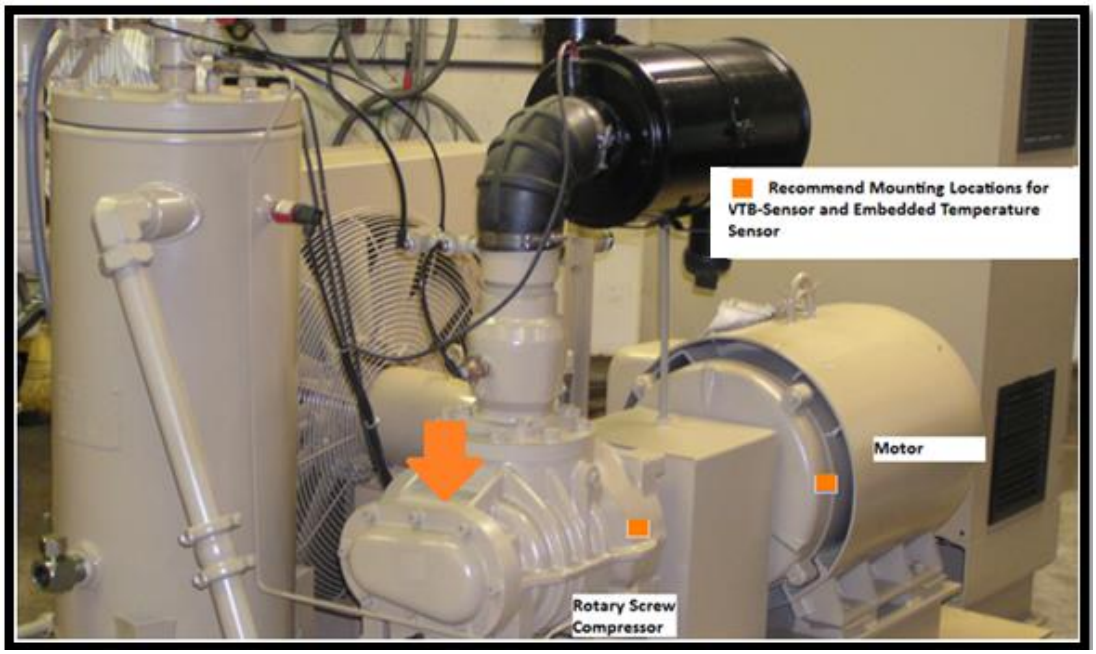

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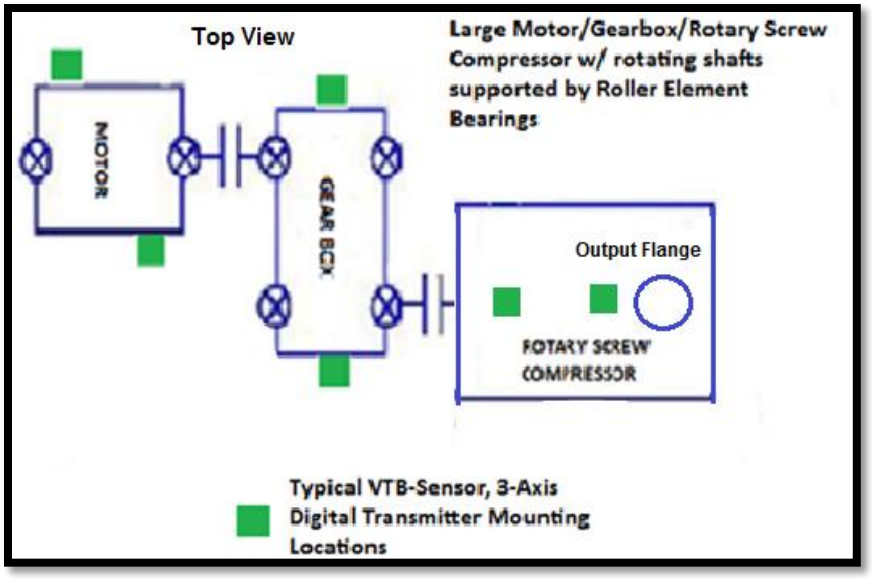

The dual 3-Axis sensor provides a unique vibration signature for each monitoring point that can be compared to other similarly located machines to insure optimal machine performance and plant wide reliability.

To provide the best machine casing location and sensor mounting procedure for the VTB-Sensors, please let our reliability team aware of the drive & driver components, and the existing environmental conditions.

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 of the common machine vibration and temperature faults.

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Rotary Screw Compressor - Common 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. Recall that vibration due to imbalance alone (discounting resonance) will increase as a function of the speed squared. 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	Radial, Axial	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.

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Rotary Screw Compressor	Lobe Mesh Frequency – Speed of Male Rotor X Number of Lobes; or, Speed of Female Rotor X Number of Lobes	Radial, Axial	Velocity, in/sec, rms	As a starting point, a new compressor can exhibit vibration levels around 0.155 in/sec rms; but, overall vibration levels approaching 0.282 in/sec rms needs to be checked out. Large rotary screw compressors with component faults can exhibit high acceleration levels up between 6 to 15 g pk (4.3 to 10.6 g, rms).
Rolling Bearing Defects with Visible Damage to the Bearings	1X to 10X 10X to 50X	Radial	Acceleration, G Pk; 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 can 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, or excessive bearing temperature.
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.
Gearbox/Loose Bearing Fit	1X RPM, Harmonics GMF, 2GMF, and/or 3GMF	Radial	Velocity, in/sec, rms	Such excessive clearance can be caused by either by extensive bearing wear or by improper fit onto the journal bearing during installation. Left uncorrected, it can cause excessive gear wear.
AC Motor Windings, Motor Roller Bearings, and Gearbox Roller Bearings Failures due to 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.

Rotary Screw Compressor

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Traditional Vibration Switches and 2-Wire Loop Powered Transmitters – Pros and Cons

Mechanical Vibration Switches	PROS • Multiple hazardous location and agency ratings • Basic unit without hazardous approvals or start-up delays are inexpensive and requires a maximum of two wires to shut-down the process equipment
	CONS • Limited frequency response- typically 0 to 100 Hz • By their design, these shock devices are sensitive to Acceleration (G) only • Acceleration is not best vibration detection measurand for low RPMs • 1 G to 10 G setpoint accuracy is unknown • Setpoints below 1 G are unstable • No trending capabilities or analysis capabilities • No advance warning about the deteriorating condition of the machine • No built-in temperature sensors • Sensitive to one axis only
2-Wire Loop Powered Vibration Transmitters	PROS • Multiple hazardous location and agency ratings • Industrial grade steel casing with electronics potted with epoxy • The 4-20mA can be run over long distances with minimal signal losses compared to voltage type signals • Saves on cable wire because it only needs 2 wires to function • Better frequency response than a mechanical vibration switch, typically 2 Hz to 1500 Hz for Velocity and 10 Hz to 1500 Hz for Acceleration • Optional built-in temperature sensors
	CONS • 4-20mA signal is highly susceptibility to indirect and direct two way radio interference • There are no field accessible calibration potentiometers to adjust, so, this electronic device is simply a pass/fail and disposable unit • There are no fault protocols for problem transmitters • Sensitive to one axis only
2-Wire Loop Powered Impact Transmitters	PROS • Multiple hazardous location and agency ratings • Industrial grade steel casing with electronics potted with epoxy
	CONS • Generally require set-up with expensive hand-held meter • Vulnerable to indirect and direct two-way radio interference used in local plants and remote compressor/pump stations. • There are no fault protocols for problem transmitters • Essentially the transmitter only counts vibration (G) peaks within a reset time which can result in false trips • There are no multiple acceleration (G) pk threshold settings • There are no lower than threshold acceleration trending features • Other than counting the G pk above one threshold setting, there is no quantifying of the detected impacts • This device as designed, is not suitable for detecting or quantifying combustion gas

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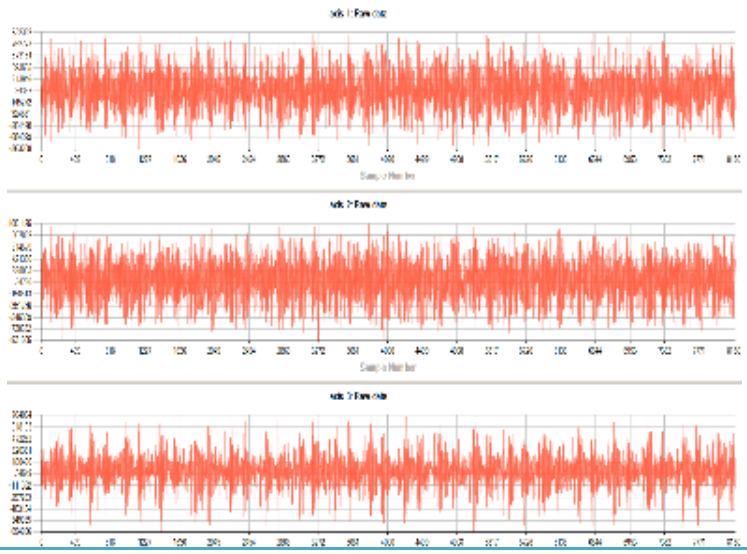
	engine detonation • No built-in temperature sensors
VTB-Sensor/VTB-Impact/VTB-Detonation and VTB-COM (VTBNet Solution)	PROS • CSA, CUL, CL I Div. 2 Groups A,B,C,D, IECEx (pending) • Dual triaxial sensors and one temperature sensor • Wide frequency and temperature range • Smart addressable microcontroller for onboard signal conditioning • Acceleration or Velocity vibration measurands • Firmware configurable band-pass filters • Firmware configurable for reciprocating compressors – impact severity • Firmware configurable for abnormal combustion gas engine detonation • Automatic sensor self-test diagnostics and dual sensor verification • Unique 3-Axis vibration or impact signature can be viewed with VTB-Client (see example of machine signature below) • Multi-color sensor status LEDs • Variety of communications are available to connect VTB-COM to the control systems: ModBus TCP/IP, USB, wifi, cellular (3G/4G) • Relays are available for machine control applications • VTB-Client software is provided with the VTB-COM. For each VTB-Sensor/VTB-Impact, It is used to view dynamic overall vibration, raw dynamic time waveforms, impact time waveforms, and FFTs
	

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Conclusion

With a combination of best practice techniques, correct setting of vibration and temperature alarm settings, and interpretation of vibration waveforms, your process equipment assets can be protected against rising 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 for 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. 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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