VTBNet™ –Low Cost and Practical approach to Vibration Monitoring for Reciprocating Compressors

Reciprocating compressors are positive displacement machines in which the compressing and displacing element is a piston having a reciprocating motion within a cylinder.There are two types of reciprocating compressors- one type requires a combustion gas engine or an AC motor (high speed separable) which may be connected to a gear box to drive the coupled compressor. Operating speed is typically between 900 and 1,800 rpm. Separable units can have single or multiple stages. They can be skid mounted, easy to install, and can be easily moved to onshore and offshore locations.

The other type has internal powercylinders (low speed integral) that drive the compressor. These units run at speeds between 200 and 600 rpm. They are commonly used in gas plants and pipeline service where fuel efficiency and long life are critical. Integral compressors may be equipped with two to ten compressor cylinders.

Many plants rely heavily on mechanical maintenance personnel to keep the reciprocating compressorsrunning, but periodic machine monitoring with vibration data collectors is not the best way to evaluate an important machine because critical vibration information can be missed.

It is ultimately up to the manufacturer or plant owner to decide what levels of vibration monitoring is adequate for protecting and monitoring their plant equipment assets. The table below is intended to point out the commonly used vibration devices and their application disadvantages for the protection of plant equipment. The table is for informational purposes only and the empirical evaluation of your vibration device and application is recommended.

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. 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. Another possible reason that the switch did not trip initially to the hammer impactis because the internal mechanical components may have become corroded due to ingress of moisture or ambient corrosives. Therefore, with corroded internal components, lowering the g level setpoint for test purposes will not allow your mechanical switch to trip. **Basically, there are many non-functional mechanical switches in the field and your plant equipment assets are not properly protected against excessive machine forces.** Mean Time Between Failures (MTBF) numbers are not listed on product data sheets or product manual.
Two-Wire Loop Powered Vibration Transmitters	Traditional 2-wire loop powered vibration transmitters utilize RMS detection circuitry which will not detect any mechanical looseness problem because the impacts do not affect the overall level of the signal output. 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 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. Mean Time Between Failures (MTBF) numbers are not listed on product data sheets or product manual.
Two-Wire Loop Powered Impact Transmitters	The 1st generation impact transmitter has been around for many years. Because there is only one adjustable threshold level, only the impact pk levelabove the threshold level is detected and counted within a preset time frame. This indicates that all the impact pk levels below the threshold level are not detected and cannot be trended for condition machine analysis. For example: Assume the adjustable threshold level is set to 6 g, and the impact levels within a specified window are between 2 to 4 g's. These low level impact peaks will not be detected nor trended for analysis by reliability professionals who could use this information to assess the deteriorating condition of the reciprocating machine. Mean Time Between Failures (MTBF) numbers are not listed on product data sheets or product manual.
Electronic Vibration Switch with Built-in Sensor	Traditional electronic vibration switches w/ internal sensor utilize RMS detection circuitry which will not detect any mechanical looseness problem because the impacts do not affect the overall level of the signal output. Internal electronic components have a limited temperature range which restricts an electronic vibration switch from hot machine casing temperatures, e.g., combustion gas 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 process equipment. 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). 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. Mean Time Between Failures (MTBF) numbers are not listed on product data sheets or product manual.

Reciprocating Compressor - Vibration Monitoring

In the past, operators have used mechanical and electronic vibration switches for continuous vibration monitoring. The driver and driven components are accessible, but, without the use of 3-axis digital sensors, the single axis vibration devices are less likely to detect mechanical looseness, valve closure, or impeding roller bearing failures. Today, with the latest innovations from Machine Saver, Inc., a new technology can be coupled to a practical approach to reliably detect, monitor, analyze, and protect reciprocating machine assets with a our state of the art digital transmitters with integral cable assemblies, minimal instrumentation wiring, and an industrial computer configured with impact severity and vibration monitoring software. Any instrumentation wiring from the industrial 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.

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

VTB Sensor is 3-axis (X,Y, and Z) digital and temperature transmitter with integral 10foot (3 meter) cable can detect rotational and structural problems (low frequency), e.g., imbalance, misalignment, defective rolling bearing problems (high frequency) in their early stages. The sensor can simultaneously detect in three measurement planes (X,Y, and 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 3-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 VTB Sensor.

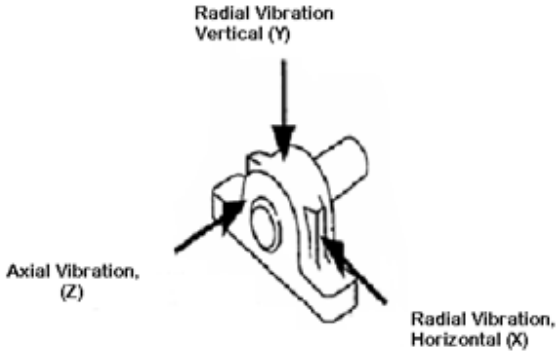


Figure 1., Roller Bearing - Shaft Vibration Measurement Planes

VTBCom™

VTB Com is an industrial communications computer designed to interface and monitor the digital signals coming from VTB Sensor. VTB Com can log the digital signalsfrom several VTB Sensors and communicate the data to other computers using a variety of digital communications such as: Ethernet, USB, GSM and wireless systems. VTB Com has 4 independent CAN bus channels that can each power and communicate up to 24 daisy-chained VTB Sensors- for a total of 96 VTB Sensors with a cable range of 329 feet (100m).

VTBNet™Condition Machine Monitor/Protection System

By using VTB Sensor and VTB Com, sensor computer together, VTBNet becomes a cost-effective online, vibration system that can be easily installed to detect and protectreciprocating compressors. 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 reciprocating 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 or only one intrinsic safety barrier is required for many of VTB Net sensors in Zone 0 / Div. 1 hazardous areas; (11) Dependable with a limited warranty

VTB-COM

VTBSensor

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 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 3-axis vibration detection and temperature into one digital transmitter, one transmitter can take the place of seven sensors.

For small reciprocating compressor 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. VTB-Net 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) Reciprocating compressors (air) may have a mix of sleeve bearings and roller bearings. Simply mount the VTB-Sensor as close as possible to the roller bearings.

5) 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.

6) On less expensive motors, reciprocating 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. This area will have the most wear, and is most likely to have problems.

7) 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.

8) The VTB-Com can be mounted inside a NEMA 4X, IP65, agency approved enclosure (UL, CSA, IEC, ATEX) with a built-in window. To avoid any overheating concerns, verify that there is at least a two inch space from the edge of the VTB-Com and all four sides of the enclosure. The enclosure

must be resistant to ambient air corrosives, e.g., hydrogen sulfide (H2S), and hazardous gases. Shelter the enclosure from direct sunlight and verify that the input/output glands, strain reliefs, and instrumentation wiring are rated for the applicable hazardous location. **To recommend the best enclosure, glands, strain reliefs for mounting the VTB-Com, please contact our team to assist you.**

9) The recommended wiring format is 20 to 24AWG/120 ohms, 4 conductors andshielded twisted pair cable. Purchasing this wire from Machine Saver, Inc is highly recommended.

Small Reciprocating Compressors

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 for small reciprocating compressors

Motor and Gearbox, or Motor and Belt Driven Reciprocating Compressor (Configured w/ Roller Bearings) - Vibration and Temperature Faults

Machine Component/Fault	FrequencyOrder	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, pk	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, pk	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, pk	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, pk	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, pk	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, pk	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, pk	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 ofaxial vibration can occur.
Motor/Shaft/Coupling Misalignment	1X,2X,3X 4X,5X,6X, Low Level Harmonics	Axialand/or Radial	Velocity, in/sec, pk	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 RPM	Radial, Axial	Velocity, in/sec, pk	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.
Rolling Bearing Defects with Visible Damage to the Bearings	1X to 10X	Radial	Velocity, in/sec, pk	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 10X 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, pk	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, pk	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 andRoller Bearings Gearbox Roller Bearings (Overheating)	1X Motor RPM	Radial Axial	Velocity, in/sec, pk	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.

Separable and Integral Reciprocating Compressor - Vibration Monitoring Levels and Application Considerations

For monitoring medium to large reciprocating compressors, the recommendations provided by the equipment manufacturer should be followed. For reciprocating compressors, consider the following industry vibration monitoring standards- API 618, the Vibration Institute, ISO 13707, ISO 10816, and the European Forum for Reciprocating Compressors, "Guideline for Vibrations in Reciprocating Compressor Systems, specifically pages 11 – 13.

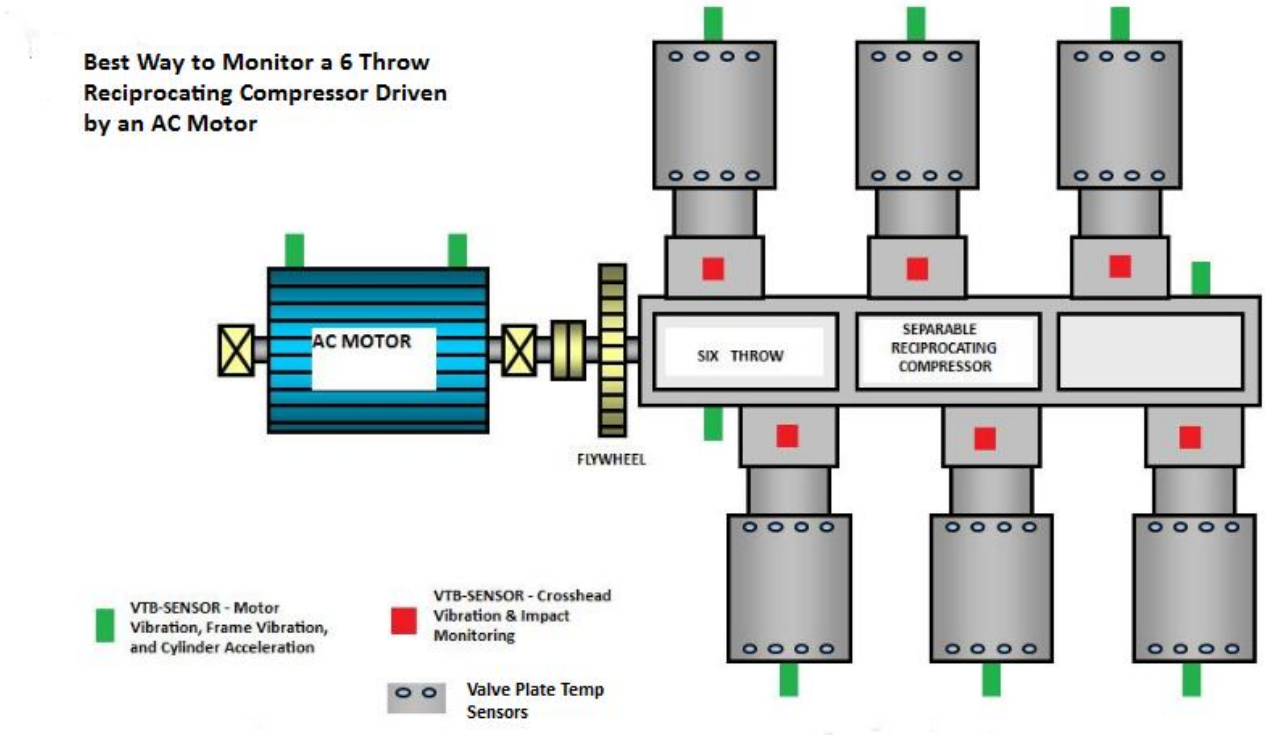
The following recommendations are offered as a starting point. Further inquiry into the condition of the compressor is required if:

- in comparison to past machine problems and other similar machines, any vibration frequency increases in amplitude
- the compressor frame vibration level at the crankshaft centerline exceeds 0.2 in/sec pk (5.0 mm/sec pk)
- the vibration amplitudes of the compressor cylinders exceed 0.3 in/sec pk (7.5 mm/sec pk)

Separable and Integral Reciprocating Compressors- Frame Vibration, Impact, and Temperature Monitoring Considerations		
Machine Component/Fault	**Vibration/Temperature**	**Comments**
Frame Vibration	Velocity, in/sec, pk	Frame vibrations are due to gas load forces (in the direction of piston rod movement), inertial load forces, and reciprocating & rotating masses unbalance forces. Foundation problems can also be detected when monitoring for frame vibration. The single most costly item on any reciprocating compressor or engine is the crankshaft. Mount VTB-Sensor horizontally on the main frame (crankshaft centerline) and opposite of each main bearing. For imbalance and misalignment purposes, the frame vibration should be monitored between 1X to 3X of compressor RPM. Catastrophic events such as breaking a piston rod or losing a counterweight will create a sudden compressor imbalance. This imbalance condition will result in high crankcase vibration. Above 3X to 10X of compressor RPM, it is recommended for the overall vibration levels to be monitored in the direction of the piston rod. The VTB-Sensor, digital transmitter configured with dual 3-axis sensors is ideal to monitor the bi-directional movement of the piston rod.
Crosshead Vibration (Impact Severity)	Acceleration, g, pk	A VTB-Sensor configured for impact detection can monitor and protect the machine for: cracked rods, worn crosshead pins, loose crosshead bolts, loose or cracked rod nuts, loose bushing to pin connections, loose shims, debris ingestion, and liquid carry-over. Most piston breakage is due to repeated liquid carry over. You will need one VTB-Sensor mounted vertically over the frame extension per compressor cylinder. Note: Impact levels in excess of 2 g pk above the overall pk vibration levels should be monitored and checked out. The 3-axis detection capability of the VTB-Sensor is ideal to detect and monitor for excessive crosshead clearance.
Suction/Discharge Valve Temperature	Temperature above 180°F (82°C) should be checked out. Monitoring the valve covers provides information on the relative temperature among the valves.	Valves can overheat due to valve or ring leakage, worn valves, stuck, clogged, or closed valves. Cylinder valves are the most critical components which strongly affect the efficiency and reliability of the compressor. Valve defects are responsible for most of the unscheduled maintenance events. Sole monitoring the temperature of the valve is not enough information to find the root cause of the cylinder failure. A sudden change in relative temperature values indicates a change in the sealing ability of the cylinder. The best temperature measurement is made in a thermowell in the valve cover. You may also need to consider the requirement for explosion proof enclosures for gaseous applications.
Crankshaft Bearings Temperature (Main Bearing)	Temperature above 185°F (185°C) should be checked out.	Elevated temperatures can be caused by rotor rub and worn fluid-film bearings.
Connecting Rod Bearing Temperature	Temperature above 175°F (80°C) should be checked out.	These bearings can be roller bearings. Verify and monitor accordingly to bearing type.

Cylinder Acceleration	Acceleration, g, pk	Mount the VTB-Sensor axially on the compression cylinder. This will provide vibration information that can be combined with the suction/discharge valve temperature readings to assess the condition of the cylinder valves.
Power Cylinder Head **(Integral Only)**	Acceleration, g, pk	The VTB-Sensor, configured for 1 Hz to 6 KHz frequency response, must be mounted vertically and as close as possible to the power cylinder head covers to detect the following vibration patterns-machine impacts (valve intake/exhaust closure, chattering rings), possible gas leakage (cylinder blowby and leaking valves) and engine detonation. On a similar application, for combustion gas engines – there are spacing and sensor mounting room issues, so, the preferred VTB-Sensor mounting location will be horizontal and above the engine block centerline and in the vicinity of the power cylinders. Traditionally, power cylinders are monitored individually with a sensor, or, the sensors are arrayed between the power cylinders and a tach signal (crank angle) is used to locate the misfiring power cylinder. Crank angle is the angle after top dead center at which peak firing pressure occurs.
TurboCharger **(Integral Only)**	Velocity, in/sec, pk	These gas engine enhancers can operate at very high RPMs. You will need to obtain the RPM from the manufacturer. To avoid the effects of low frequency signals of frame vibration (1X to 10X) on overall vibration levels of the turbocharger, use a high pass filter to capture the vibration levels at or around the frequency of the turbocharger. For example: If a turbocharger runs at 10,000 RPM (167 Hz), then use a high pass filter that begins at 120Hz to omit the low frequency (1X to 10X) frame vibrations. To avoid VTB-Sensor overheating issues, mount the VTB-Sensor on the cold side of the turbocharger. Thecold side deals with fresh air as opposed to the hot side that deals with hot exhaust gas.

Best and Minimum Way to Monitor a Reciprocating Compressor (Separable and Integral)



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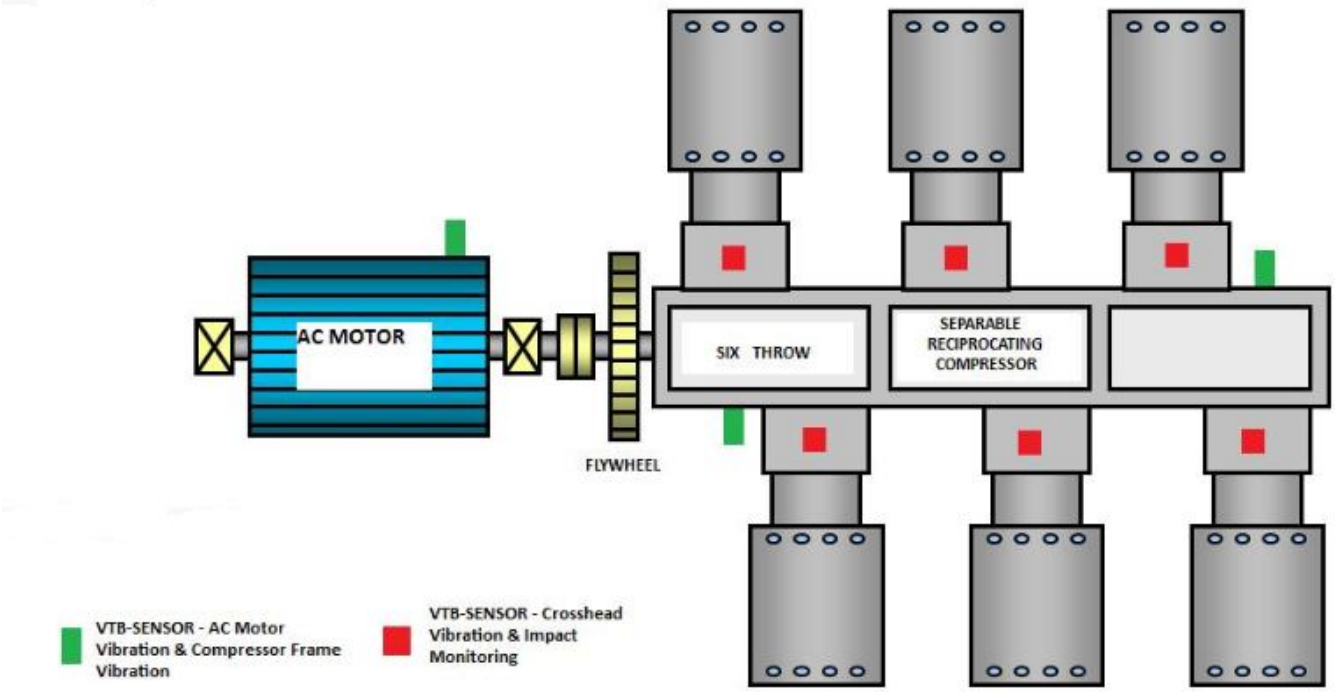
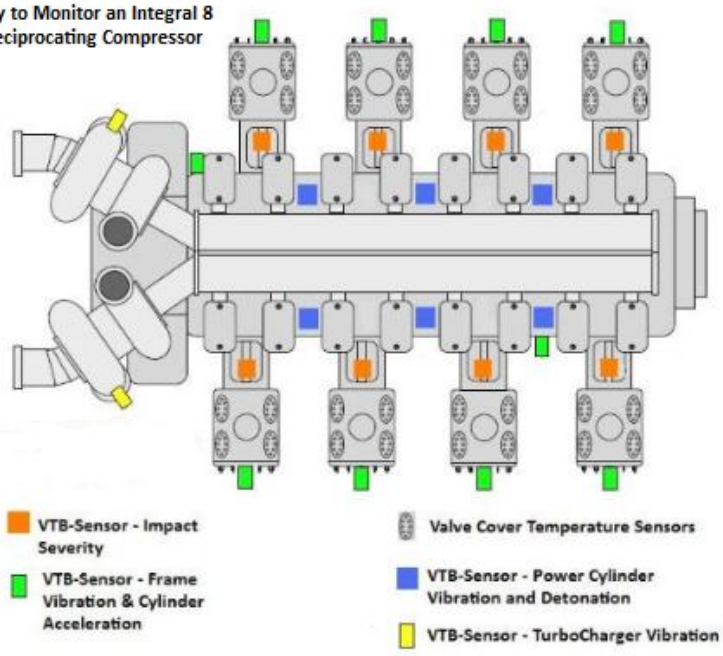
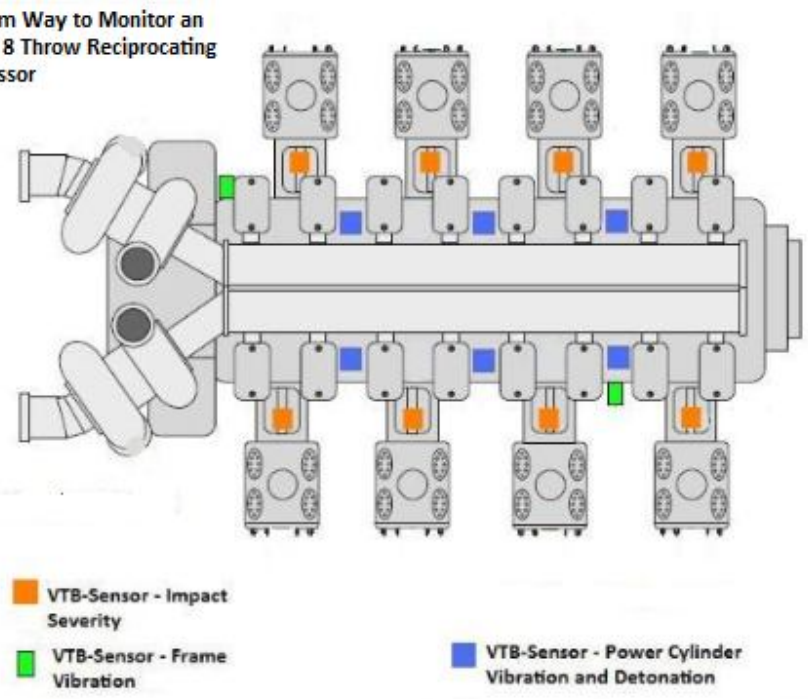


Best Way to Monitor an Integral 8 Throw Reciprocating Compressor



Minimum Way to Monitor an Integral 8 Throw Reciprocating Compressor



Conclusion

With a combination of best practice techniques, correct setting of vibration and temperature alarm settings, and interpretation of vibration spectra, your reciprocating machine assets can be protected against mechanical looseness, increasing framevibration and elevated valve temperatures. These machine faults can cause complete machine failure which cause plant processes to stop running.

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

References

1. A. Almasi, "Reciprocating Compressor Optimum Design and Manufacturing with respect to Performance, Reliability, and Cost", 2009, World Academy of Science, Engineering and Technology.
2. Bryan R. Long, Ph.D., P. Eng., and David N. Schuh, P. Eng., "Fault Detection and Diagnosis in Reciprocating Machinery", provided by a machinery consultant company- Beta Machinery Analysis.
3. Bruce M. Basaraba and James A. Archer, "IPT's Rotating Equipment Handbook", 2000, Quebecor Jasper Printing
4. Claire Soares, "Process Engineering Equipment Handbook", 2002, McGraw-Hill Handbooks.
5. European Forum for Reciprocating Compressors, "Guidelines for Vibrations in Reciprocating Compressor Systems", Third Edition – May 2012.
6. James E. Berry, P.E., "Vibration Diagnostic Handbook", 2004, Technical Associates of Charlotte P.C.
7. Ralph T. Buscarello, "Practical Solutions to Machinery and Maintenance Vibration Problems", 1991, Update International, Inc.
8. Steven M. Schultheis, Charles A. Lickteig, and Robert Parchewsky, "Reciprocating Compressor Condition Monitoring", 2007, Proceedings of the 36th Turbomachinery Symposium