RECIPS - Customer Driven Solution for Replacing Mechanical Vibration Switches and Two-Wire Loop Powered Vibration & Impact Transmitters

Mechanical Switch and Loop Powered Transmitters

Similar to the mechanical vibration switch, the vibration transmitter has been with us for many years. Despite the outdated technology, they remain popular to process equipment manufacturers or service companies who rely heavily on quantity discounts obtained from the suppliers of vibration system hardware. The loop powered transmitter only needs two wires to work, because the power and signal use the same twisted pair of wires. Among other features, it is reasonably unaffected by the distance from the transmitter to the control room. The cabling can be added or removed without changing the 4 20mA, DC accuracy - a unique attribute for PLC, DCS, or SCADA control systems.

The impact transmitter was created after realizing that traditional electronic vibration devices with RMS detecting circuitry **CANNOT** adequately detect or monitor the reciprocating motion (acceleration) present in-line and over the crosshead and piston rod driving the compressor cylinders. The traditional impact transmitter has internal circuitry to detect and measure high amplitude and short duration acceleration, g, pk, but, the transmitter only counts high amplitude g, pks above one threshold level that can be caused by high ring-down pks during the reciprocating motion. Without a way to quantify the detected impact and ring-down profile, the 4-20mA signal may result in false trips.

Many of our valued customers have requested for our reliability team to review their process equipment applications and to provide a reliable solution to replace their dated mechanical vibration switches, and loop powered vibration & impact transmitters. Including our own comments, the table below provides some of the vibration & impact device problems that our customers have experienced and expressed to our team.

Traditional Device	Reliability Concerns
Mechanical Vibration Switch	1. In 1995, API 618, 4th edition, the standard for reciprocating compressors has specifically eliminated the mechanical switch as a vibration device due to its inherent reliability issues. To this date, the mechanical vibration switch is not specified in any American standard publication for any type of process equipment or machinery. 2. Mechanical switches which are basically inertia activated devices that require large changes in g forces to trip. There are process equipment in plants that are operated at 35 RPM or less 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. 3. The normally closed (NC) and normally open (NO) contacts on the internal microswitch (SPDT) can become erratic and unstable during the mechanical resonance (high g levels) encountered during the start-up of a large motor and pump set. 4. 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. The issue here is that repeating this test over time can dislodge the internal adjustable spring, armature, or some mechanical part or component. The switch may still work partially, but, the switch is basically unreliable. 5. Another application concern is the number of units in the field that that have internal corrosion due to ingress of moisture or ambient corrosives. There are no useful signals or mechanical devices to give the operator constructive notice that the mechanical switch is defective. The unprotected machine will then run daily for years until the operator tries lowering the G level setting for test purposes. If the internal corrosion is severe, the switch will not trip no matter how low the g level setting. ***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. Basically, there are many non-functional mechanical switches in the field and your process equipment investments may not be properly protected against excessive and destructive machine forces.***

Two-Wire Loop Powered Vibration Transmitters

1. Compared to similar off-the-shelf devices a remote plant received vibration transmitters that were Dead On Arrival (DOA).

2. Compared to similar off-the-shelf devices a local plant received vibration transmitters that are not functional for the application because the units are stuck at a current value between 4.00mA and 20.00mA, DC.

   The two-wire loop powered vibration transmitter is a mature product, so, the end-user customer may not test the units for functionality before they are mounted on the machine. Therefore, a problem transmitter that is stuck at a low level current output can go undetected in the field even if the machine is running in an unbalanced condition. Conversely, a problem transmitter stuck at a high level current output may not allow the machine to start-up.

3. The control room has recorded erratic spikes in the 4-20mA analog output that can be correlated to rising machine temperatures between 70°C and above.

4. 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.

   For example, a transmitter designed with proper fault protocols (internal electronic circuitry), may indicate problems with the sensor or the wiring. Should a fault develop with the sensor or the wiring, it could be apparent to the operator in the control room because the transmitter could output a 0 mA for an open wire or sensor defect, or, exceed 20mA if there is a short in the wiring or in the sensor.

5. Although these devices are labeled with CE certification, they are vulnerable to direct and indirect two-way radio interference created in many local and remote process plants.

   In a recent service call, our field technician was able to isolate and troubleshoot the root cause of the RF interference by performing the following steps: 1) vibration transmitter was disconnected from the cabling that leads to the control room; 2) PLC was set to passive mode; 3) a 4-20mA process meter was set to “source” and connected to the cabling that leads to the control room; 4) 2-way radio, 10 watts, keyed near the critical process equipment ;and, the control room no longer displayed any RF interference. Conversely, the transmitter was reconnected and the PLC was set back to active mode. Once the 2-way radio was keyed, the RF noise was seen again on the display screen in the control room. Even with the use of single and multiple ferrite beads and multiple turns on the two leaded wires, the field technician was not able to remove the RF noise going to the control room.

Once installed the performance of this device can be verified with a portable vibration shaker system, but, in the field or back at the factory, they cannot be recalibrated. There are no calibration potentiometers to adjust, so, this electronic device is simply a pass/fail and disposable unit.

Traditional Impact Transmitter

1. Like the vibration transmitter, these devices are especially vulnerable to indirect and direct two-way radio interference used in many local and remote compressor/pump stations.

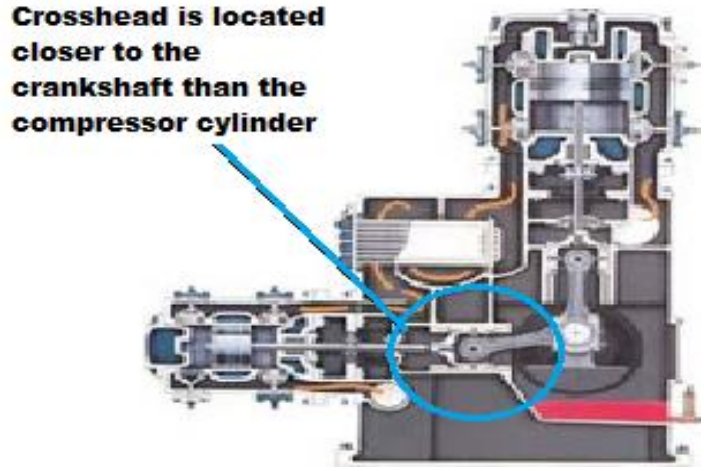
2. Unlike the two-wire loop powered vibration transmitter, the impact transmitter is costly and generally cannot be used straight out of the box. It requires an expensive hand-held meter loaded with firmware or software to set-up the impact threshold settings for each transmitter. While the machine is running, an operator has to remove a number of screws to obtain access to adjust the different settings prompted by the hand-held meter**.** If you forget to fasten and tighten the screws after you adjust the settings, the transmitter is subject to indoor moisture, dust, and other airborne contaminants. The moisture inside the transmitter will turn into a gas that may eventually corrode the inside circuitry of the transmitter. Depending on the level of corrosion, this will cause intermittent problems with the unit. If the compressor is located outside, then the open transmitter will be subject to the outdoor elements, e.g., rain water and depending whether the transmitter is located on top of the casing of the cross-head; or, below the casing of the cross-head, the impact transmitter may fail more quickly.

3. It is important that you verify the following after you remove the screws to make reset time and threshold level adjustments- Verify that the variable potentiometers are in line with the open and threaded holes. If the potentiometers are not in line with the holes, then, you may have an older transmitter that has caused our customers lots of field problems, e.g., 4 20mA analog output is stuck and unit is unresponsive to vibration, pk and cannot be set-up with the hand-held meter.

4. The impact transmitter has only one adjustable threshold level, therefore, only the impact g, pk level above the threshold level are detected and counted within a preset time frame. This indicates that all the impact g, 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 gs. These low level impact peaks will not be detected nor trended for analysis by reliability professionals who could use this information along with other process variables to assess the condition of the reciprocating machine.

5. On the integral reciprocating compressors (built-in gas engine), the large units will make it challenging to set-up the impact transmitter using the hand-held meter set to detect the pk vibration levels.

   The reasons for the low pk vibration values: 1) the integral recips are heavy cased and are mechanically designed to run smoothly; 2) the crosshead sections are located deeper in the compressor frame. The blue ellipse drawn on the crosshead below indicates how deep this component can be within the machine.



If an operator CANNOT obtain a strong acceleration g, pk level to set-up the impact transmitter, then, you cannot properly set an impact threshold level. BASICALLY, the plant is stuck with a lot of non-functional transmitters in the field and your process equipment investments ARE NOT properly protected against excessive impact forces.

6. A properly set-up impact transmitter can be suitable to detect and monitor basic mechanical impact severity, but, it was not DESIGNED to detect and monitor abnormal combustion gas engine detonation. This device responds to impact events but essentially only counts acceleration g, pks during a time period based on the running speed of the compressor. You will not be able to discern the signature of combustion gas engine detonation from the 4-20mA output signal. How would an operator know if the 4-20mA signal is indicating an unlubricated connecting rod and crosshead, or, the beginnings of mechanical looseness, or abnormal gas engine detonation?

VTB-Sensor / VTB-Impact

VTB-COM

VTB-Sensor is addressable with a smart programmable design enabling reliability engineers and maintenance professionals to have a one-size-fits-all vibration sensor. The VTB-Sensor is suitable for rotating machine applications such as motors, pumps, fans, compressors, engines, centrifuges, cooling towers as well as reciprocating compressors and pumps. The sensor provides overall vibration level outputs for the X, Y and Z axis in acceleration & velocity, and provides a temperature output.

The **VTB-Impact** is similar to the VTB-Sensor, but, incorporates enhanced internal circuitry designed to detect, quantify, and monitor impact severity for mechanical looseness.

VTB-COM is a communication gateway which monitors the VTB-Sensors via the CAN bus network. This communications gateway logs information from the VTB-Sensors and communicate the information to control systems (PLC, DCS, SCADA) or remote monitoring stations (PC) using a variety of communications methods such as Ethernet, Modbus and USB. Additional connection options are available such as: wireless, Wi-Fi, and cellular (GSM).

The VTB-COM utilizes four CAN bus ports to digitally link with the daisy chained VTB-Sensors. In non-hazardous areas, each CAN bus port can communicate with up to 24 VTB-Sensors. This makes it possible to run 96 VTB-Sensor drops to one VTB-COM communication gateway. **In hazardous areas, the sum of all CAN bus ports can only communicate with up to 24 VTB-Sensors.**

VTB-Sensor - Vibration Monitoring

Frame Vibration

For the machine crankshaft and frame, VTB-Sensor should be mounted horizontally on the frame and centerline and opposite of each main bearings. Reciprocating compressor malfunctions of interest are associated with running speed, e.g., crankshaft and crankshaft counterweight failure, connecting rod failure, frame-foundation looseness and change in piston rod, crosshead pin or connecting rod loading.

Machine internal forces of concern:

1) changes in crankshaft condition or loss of crankshaft counter weight can produce unbalance force of the system at one times running speed (1X) component;
2) connecting rod failure that does not immediately stop the crankshaft will change the (1X) unbalance component;
3) in addition to rod load forces, moment unbalance forces (1X, 2X) also act on the frame;
4) soft frame to foundation connections reduces stiffness and increases the amplitudes caused by the road load forces and moment forces (1X, 2X, 3X…);
5) for the horizontal reciprocating compressor, the lateral forces are more damaging than the axial forces.
6) crankshaft is the most expensive component inside the crankcase.

Since these forces and moments act directly the crankshaft and frame, the VTB-Sensor must be mounted at the frame center lined to the crankshaft and opposite to the main bearings (1X to 10X) and (10X to 100X).

For vibration monitoring, 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 0.14 in/sec rms (3.50 mm/sec rms)
- the vibration amplitudes of the compressor cylinders exceed 0.21 in/sec rms (5.30 mm/sec rms

VTB-Impact - Impact Severity

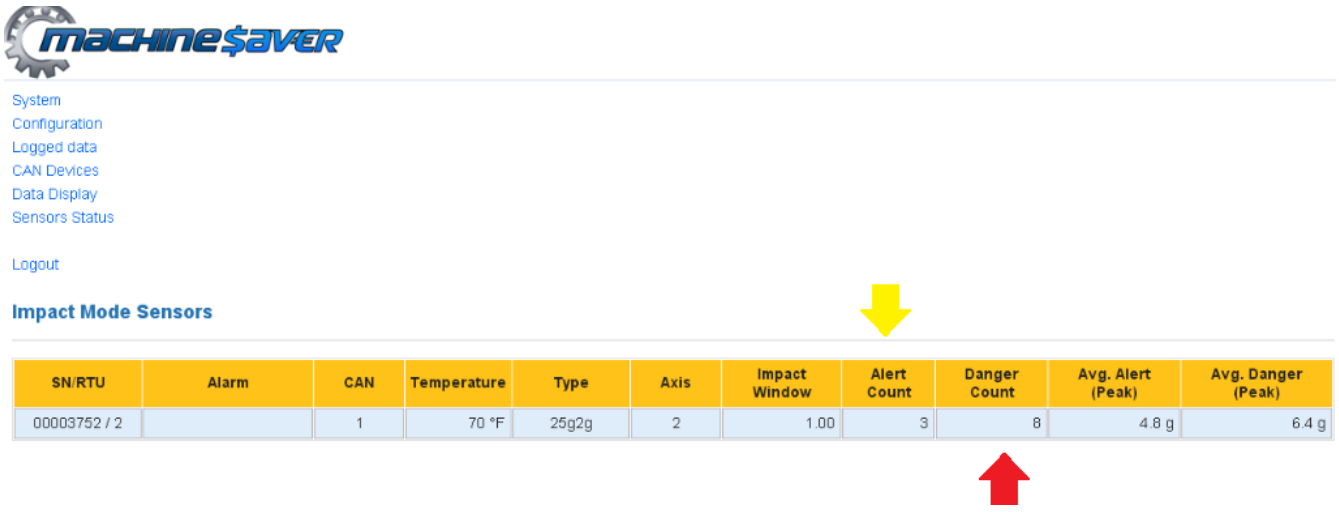
Of all the vibration measurements that can be made on a reciprocating compressor, impact detection is the most cost effective. Even for small, spared, non-critical reciprocating compressors, a VTB-Impact configured for impact monitoring on each compressor cylinder is easily justifiable

Our approach to capture and monitor for impact severity:

1) The VTB-Com Web interface menu allows machine impact configurations for running speeds between 200 and 1800 RPM.

2) It is essential that the impact signal can be detected and verified for impact monitoring accuracy, repeatability, and system reliability. Therefore, it is important that the VTB-Impact sensor is mounted vertically over the cross-head section of the compressor and connected to VTB-Com via the VTB-Impact sensor integral cable.

3) The special impact monitoring screen provides relevant impact information that allows reliability personnel to quickly assess the condition (alert and danger impact counts) of the reciprocating compressor. The headings on the left side of the screen will allow the operator to configure the protection of the machine based on the percentages of the alert or danger count.



SN/RTU	Alarm	CAN	Temperature	Type	Axis	Impact Window	Alert Count	Danger Count	Avg. Alert (Peak)	Avg. Danger (Peak)
00003752 / 2		1	70 °F	25g2g	2	1.00	3	8	4.8 g	6.4 g

To set up the VTB-Impact sensor, an operator can set up the window times (reset time) based on the calculation of 960/machine running speed (RPM). The impact threshold levels are user settable in 1 G increment from 2 g up to 20 g pk. The window time will reset continuously and VTB-Net will accurately count how many impacts occurred within the user settable impact thresholds. The amount of impacts within the reset time indicates the repeatability of the impact and the severity of the mechanical looseness. The faster (slower) the machine RPM, the less (more) length of reset time is required for verifying impact severity.

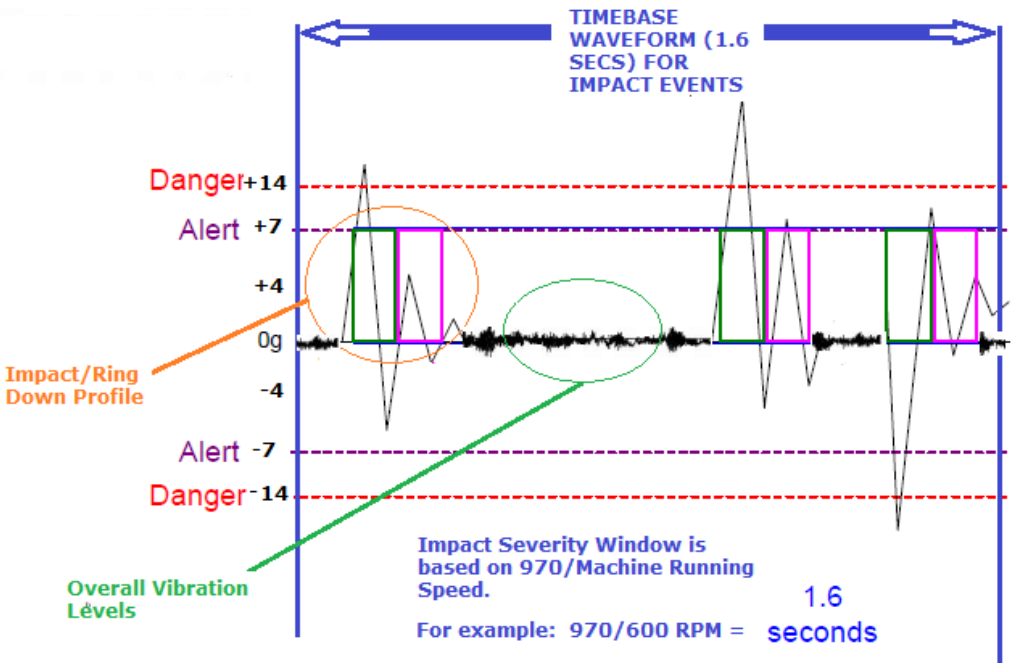
Window time example:

Machine Running Speed of 200 RPM, 960/200 = 4.80 seconds

Machine Running Speed of 600 RPM, 960/600 = 1.60 seconds

Machine Running Speed of 1200 RPM, 960/1200 = 0.80 seconds

Machine Running Speed of 1800 RM, 960/1800 = 0.53 seconds



The VTB-Impact sensor should be mounted on the frame extension of each compression cylinder to detect for impact related events associated with the axial motion of the cross-head and piston rod.

If the reciprocating compressor does not have a crosshead or the crosshead is imbedded deeper in the crankcase, then mount the VTB-Sensor as close as possible to crankshaft side. The best practice is to obtain mechanical drawings from the plant's maintenance team to decide the best place to mount the VTB-Sensor.

Due to the short duration and high frequency nature of the impact/ring down profile, the VTB-Impact will detect machine related impact problems much better than a velocity vibration sensor.

Impact acceleration related events:

- Mechanical looseness
- Loose piston or cross-head attachments
- Excessive cross-head clearance
- Loose or cracked compressor frame
- Excessive clearance in wrist pin bushings
- Excessive clearance in the main bearings
- Liquid carryover

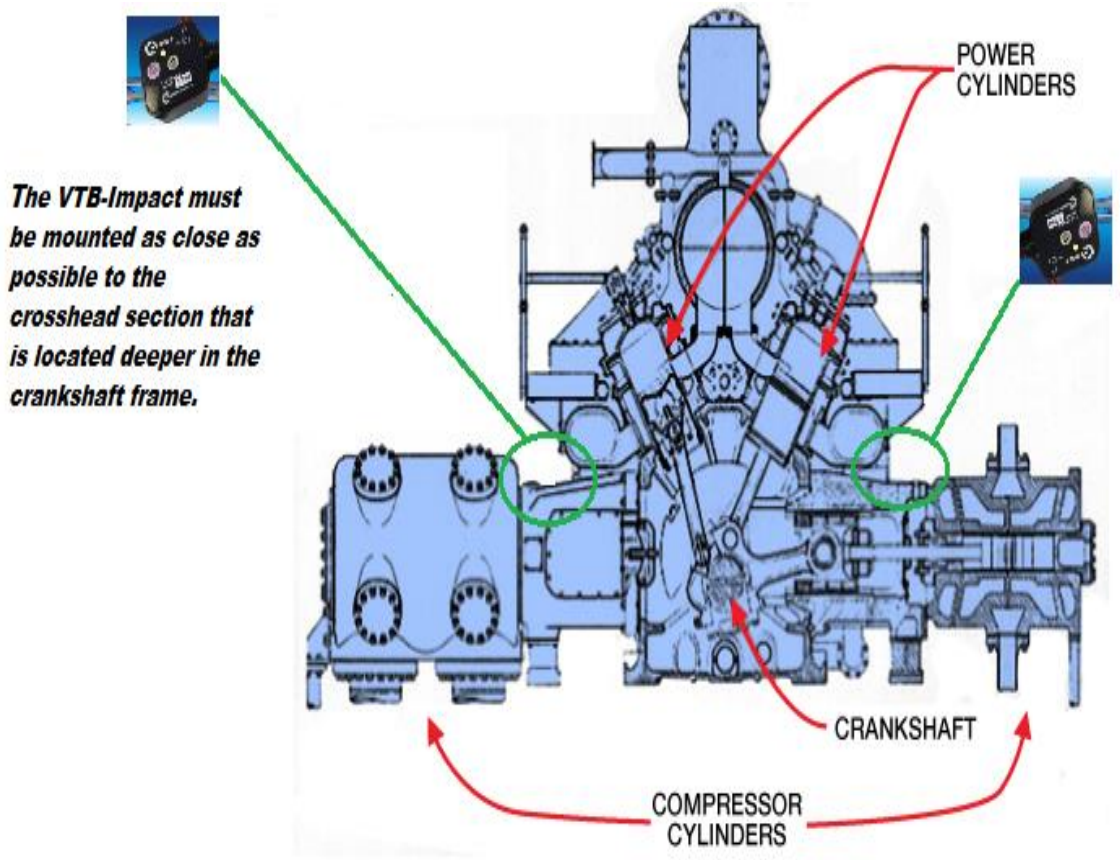
The impacts will typically occur at Top Dead Center (TDC) and Bottom Dead Center (BDC) of the piston stroke as the forces reverse. During normal operation, impact acceleration levels slightly above 2 g, pk can be trended. Depending on the type of compressor, impact levels above 3 g, pk can be mechanical looseness and should be investigated. Impact levels above 6 or 7 g, pk should cause user configured alert or danger alarms to actuate in the control room.

For some reciprocating compressors, the normal operation of the acceleration amplitude can be at a constant 3.5 to 4.0 g, pk level. This constant level can be increasingly higher for compressors that run between 600 to 900 RPM; and still higher for machines that run between 1000 to 1800 RPMs. Therefore, a higher alert and danger impact threshold setting may be required to avoid false tripping. In order to properly set the alarm and danger impact settings, first contact the manufacturer of the machine and secondly, review the machine's maintenance records. You can then compare the machine's vibration and impact data to other similarly configured machines.

VTB-Impact Application No. 1 – Integral Gas Compressor

Issue: For each compressor cylinder, what is the best practice to obtain the highest acceleration peak before mounting the VTB-Sensor permanently?

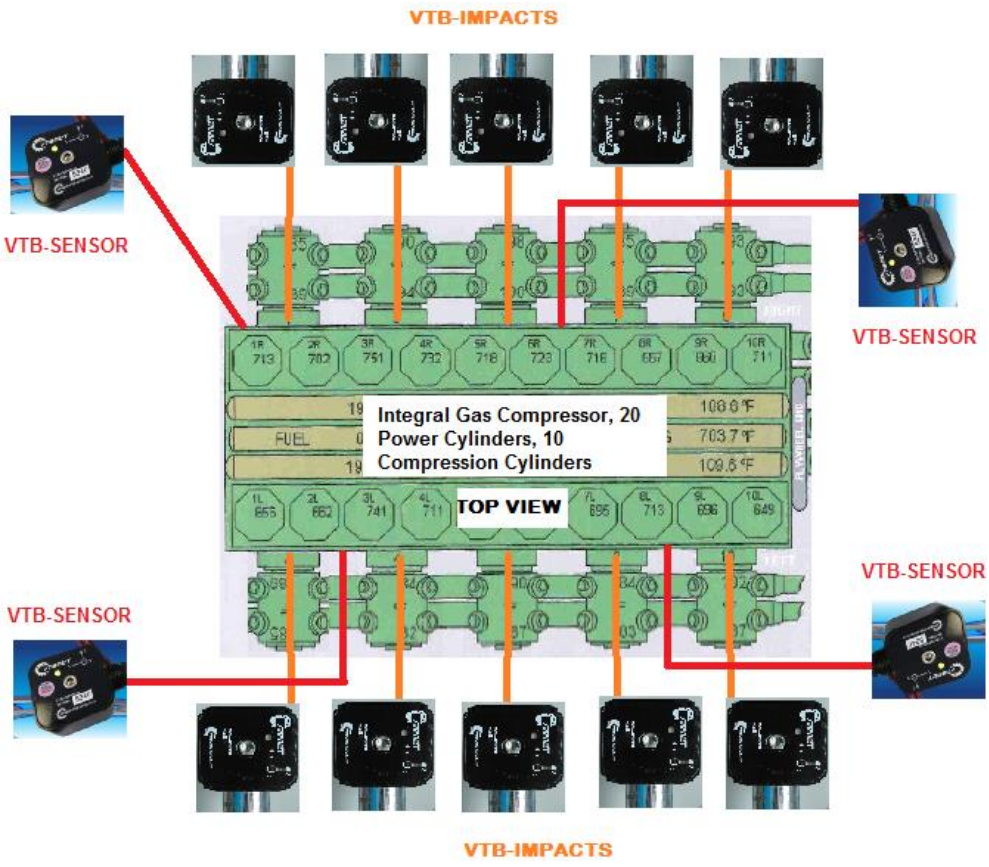
1) obtain mechanical drawings from the maintenance team to verify the best mounting location for the VTB-Sensor; 2) clean the sensor mounting surfaces from dirt, oil, and years of paint; 3) while the machine is running, an operator can use a sensor mounting disc adapter that utilizes rare earth magnets to mount the VTB-Impact temporarily around the crosshead section to locate the highest acceleration g, pk levels; 4) once the mechanical drawings are verified, the VTB-Impact can be mounted as close as possible to the crosshead section that is located deeper and closer to the crankshaft (see diagram below).



VTB-Impact/VTB-Sensor Application No. 2 – Integral Gas Compressor, 5 Compression Cylinders On Each Bank

Issue: For each compressor cylinder, what is the best practice to obtain the highest acceleration peak before mounting the VTB-Sensor permanently? How would I array the VTB-Sensors for compressor frame vibration?

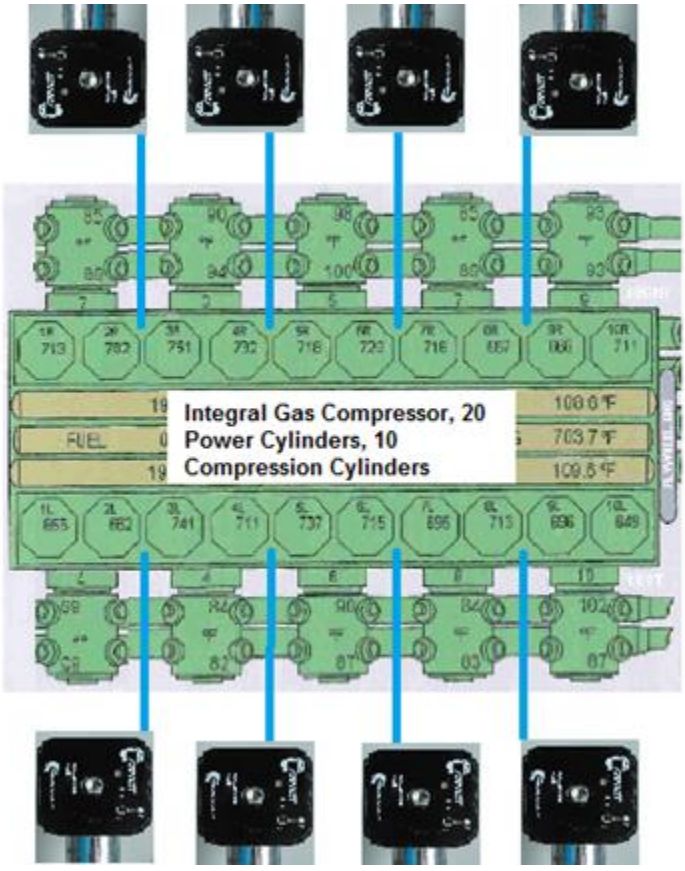
1) obtain mechanical drawings from the maintenance team to verify the best mounting location for the VTB-Sensor; 2) clean the sensor mounting surfaces from dirt, oil, and years of paint; 3) while the machine is running, an operator can use a sensor mounting disc adapter that utilizes rare earth magnets to mount the VTB-Impact temporarily near the crosshead section to locate the highest acceleration g, pk levels; 4) once the mechanical drawings are verified, the VTB-Impact can be mounted as close as possible to the crosshead section that is located deeper and closer to the crankshaft (see diagram below); 5) for frame vibration, mount the VTB-Sensor on the side of the compressor (laterally) and center-lined to the crankcase.



VTB-Impact Application No. 3 – Integral Gas Compressor, 10 Power Cylinders on Each Bank

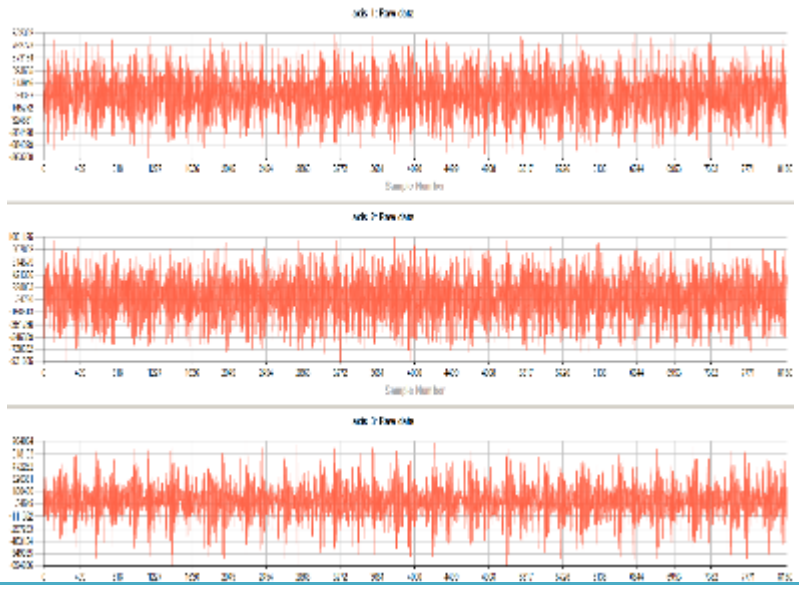
Issue: A typical detonation signal can be between 1 to 5 KHz with an acceleration g pk that varies between 15 to 75 G Pk. What is the best practice to detect this abnormal combustion and where will the VTB-Impact be permanently mounted?

1) **obtain mechanical drawings from the maintenance team to verify the best mounting location for the VTB-Sensor; 2) clean the sensor mounting surfaces from dirt, oil, and years of paint; 3) while the machine is running, an operator can use a sensor mounting disc adapter that utilizes rare earth magnets to mount the VTB-Impact temporarily near the power cylinder cover section to obtain the highest acceleration g, pks levels; 4) once the mechanical drawings are verified, one (1) VTB-Impact can be mounted on top and in between every second power cylinder cover. If there is no room on top, the VTB-Impact can be mounted on the side of the compressor (laterally) in the same area (see diagram below).**



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
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 gas engine detonation • No built-in temperature sensor

VTB-Sensor/VTB-Impact 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 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
	

Conclusion

This technical note has practical suggestions to assist you in your application. We want to support you with a reliable product that successfully and consistently detects, monitors, and protects your equipment investment. Our team can provide vibration monitoring solutions and benefits for your present application and extend their vibration expertise to your entire balance of plant. Product and application information is available at www.machinesaver.com

We want to hear from you! We encourage our customers to contact our management team at 281-507-1278 to give us your feedback. We are driven by our valued customers who can aid us in improving our products and services.

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. Claire Soares, "Process Engineering Equipment Handbook", 2002, McGraw-Hill Handbooks.
4. European Forum for Reciprocating Compressors, "Guidelines for Vibrations in Reciprocating Compressor Systems", Third Edition – May 2012.
5. Gene Ort, "Roulette and Mechanical Vibration Switches: What Are Your Odds?", 2006, CTI Journal, Vol. 27, No. 2, pp. 44- 58.
6. Ralph T. Buscarello, "Practical Solutions to Machinery and Maintenance Vibration Problems", 1991, Update International, Inc.
7. Steven M. Schultheis, Charles A. Lickteig, and Robert Parchewsky, "Reciprocating Compressor Condition Monitoring", 2007, Proceedings of the 36th Turbomachinery Symposium