Application Guide for PC420V-series LPS® Transducers

Introduction

With the availability of 4-20 mA vibration transducers, plant personnel can now input vibration information directly to their Programmable Logic Controller (PLC) or Distributed Control System (DCS). This capability allows plant personnel to trend overall vibration data on their machines, correlate vibration data to plant operating conditions, and allows plant operators to schedule maintenance tasks on machinery. However, just as other process information (such as temperature, pressure or flow) will have limits, so also does vibration. The ISO 10816-1:1995(E) standard can provide guidance in establishing or setting vibration limits for machinery.

Wilcoxon's Loop Powered Sensors (LPS®) are self-contained 4-20 mA vibration transmitters. They are purchased with a specific full-scale setting. The full-scale is not adjustable by the user. The availability of a standard for vibration measurement and condition evaluation can help to determine the best full-scale range to use in any particular monitoring environment. It can also aid in evaluating the severity of a machine's vibration condition.

This application guide will review the background of machinery vibration, 4-20 mA loop sensors, the ISO10816-1:1995(E) standard, help in selecting the proper range transducer, elaborate on installation guidelines, and provide guidance with setting vibration limits.

It is not the purpose of this document to provide detailed instructions for analyzing machinery vibration problems. There are many other useful publications that can aid in diagnosing vibration problems. Links to such useful information can be obtained from the Wilcoxon web site at www.wilcoxon.com or by calling Wilcoxon at 301-330-8811.

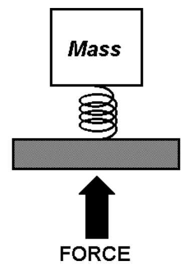
Machinery Vibration

What is machinery vibration? Why does a machine have vibration? It seems as though every treatment of vibration analysis or predictive maintenance starts with these questions. There is a very good reason why that is so. If there is no meaningful purpose or cause for vibration then there is no reason to bother with monitoring or measuring it. Fortunately, there are very good reasons to measure and trend vibration.

The first question is often answered by reference to one definition or another of vibration. Here is the definition from the Merriam-Webster Collegiate Dictionary (1996):

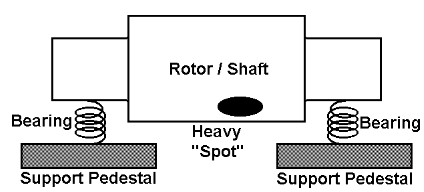
vi•bra•tion*, *noun *(1655)*
1a : *a periodic motion of the particles of an elastic body or medium in alternately opposite directions from the position of equilibrium when that equilibrium has been disturbed (as when a stretched cord produces musical tones or particles of air transmit sounds to the ear)*
b : *the action of vibrating* ***:*** *the state of being vibrated or in vibratory motion: as*
(1) : *OSCILLATION*
(2) : *a quivering or trembling motion* ***:*** *QUIVER*

In the illustration to the right, the force applied to the "base" translates to the "Mass" through the spring. If the mass were an automobile, the spring the suspension of the auto, and the force were acting on the tires then the system response would be the motion of the automobile "Mass" over the road. Most people can relate to this auto example. Bumps in the pavement cause the auto to vibrate in response to various pavement changes.



Machines have vibration because there is always some residual imbalance in the rotors of motors and shafts of machines. That imbalance will act just the same as an eccentric cam on the base of our simple spring-mass system. The imbalance will result in a sinusoidal vibration. The rotating shaft is being held in place by the bearings the machine. Because the machine shaft is turning, the vibration is repeating at the rate the shaft turns. This repetitious vibration is considered to be "periodic."

The machine bearing also acts like a spring-mass system to transmit the vibration to the machine case. The bearing has some amount of stiffness so the shaft will be allowed to move. The forces generated by the residual imbalance will be transmitted through the bearing housing. The resulting motion can be measured using vibration transducers. When the signal is observed using an oscilloscope or spectrum analyzer, it will be found to be essentially a sinusoidal signal.



To summarize, machines all vibrate because of residual imbalance in the rotating component (rotor or shaft). That imbalance translates into a rotating force vector that imposes itself onto the bearing. The bearing responds by translating the force into motion because of stiffness in the bearing housing and support structure. The resulting motion can be measured using vibration transducers.

Other problems in the machine will also evidence themselves as vibration, including:

Misalignment
Bearing wear
Faulty bearing components
Rotor and air gap problems
Gear faults
Coupling faults
Mechanical looseness
Belt drive problems

This list is not all-inclusive, but illustrates that vibration monitoring and analysis is capable of finding many machine faults. Most plants that have instituted a program of vibration monitoring have been able to report a reduction in unscheduled down-time, reduced maintenance expense, and improved equipment availability.

Process Loop (4-20 mA) Sensors

These days process sensors all seem to be 4-20 mA devices. Why is that? Why aren't they some other current or, for that matter, voltage devices? The long answer involves a great deal of history. The short answer can be likened to the great "Beta" versus "VHS" videotape format battle of a few years ago. Using 4-20 mA sensors just worked out best for most situations. So here's a moderate length answer without too much history.

Sensors can, generally, operate as either voltage-mode or current-mode devices. When voltages are used in instrumentation, great care must be exercised to avoid "stray electro-magnetic interference (EMI)." Electric and magnetic fields can impose a voltage on wires that are near them. Twisting the wire pairs helps reduce that effect by exposing both wires to approximately the same EMI effects. This means the common-mode voltage (voltage between the wires in the pair) stays approximately zero due to the balanced exposure. Shielding the wires further protects them from electric and magnetic field influence. Unfortunately, the effect is only "reduced" not eliminated. Large motors can produce current surges that develop very high fields. Power lines near instrumentation can also do the same.

If sensors are operated in the current-mode, many of the effects of EMI are effectively eliminated. While the "stray" fields are good at inducing a voltage in the paired wires, it is much harder to induce a common-mode current in shielded, twisted-pair wires. For this reason, current-mode sensors are always preferred when electrical noise pick-up must be minimized. If there are connectivity problems in the circuit and the connection resistance changes, a voltage-based circuit would have serious noise while a current-based circuit would hardly notice the resistance change.

Voltage ranges of 0-1 Volt, 0-5 Volt, 0-10 Volt, and 1-5 Volt have been used for voltage-mode sensors. Current ranges of 0-20 mA, 4-20 mA, and 10-50 mA have been used for current mode sensors. Since voltage-mode sensors are sensitive to stray noise pick-up, they are not preferred when the instrumentation wiring must be run for long distances. In short, well-controlled situations they can be used, but long wire runs near electrical equipment will likely result in noise on the instrument lines. Current-mode sensors can use longer wiring because the current in the loop is less likely to be affected by electrical equipment.

Sensors using 0-20 mA output must have a separate connection for power. When they have a zero signal they are outputting zero current and must obtain powering from some other means. 4-20 mA and 10-50 mA circuits can be powered by using circuits that consume less current than the lowest loop current for zero signals. If a sensor can be operated using less than 3 mA, then it can be operated from the "residual" loop current.

While almost any voltage could be used for powering the sensors, 24 Volts DC has become the voltage to use. Why is that? Years ago it was found that the human body could resist harmful currents from DC voltages better than AC voltages. Thomas Edison was an early proponent of DC power because of his belief in its inherent safety. In fact, his laboratory worked on developing the first electric chair (powered by AC voltage) and Edison is thought to have pushed its use of AC voltages to demonstrate the danger of AC while he promoted his own DC power systems. For other practical reasons, however, AC voltage became the electric power industry standard for generation and transmission.

DC voltages above 50 VDC and AC voltages above 30 Volts RMS are considered hazardous to human life. For example, traditional telephone circuits operate from a DC voltage just below 50 volts. The nominal voltage across a telephone line that is "on hook" is 48 VDC. Most people do not consider their telephone wiring to be hazardous.

When DC-powered circuits are critical they are often operated from battery power that uses trickle charging. Lead-acid based batteries have a cell voltage that is nominally 2.0 volts. Automotive and marine lead-acid batteries have, variously, been 6, 12, or 24 volts. Therefore, the highest voltage lead-acid DC battery useable would be 24 volts. Consequently, using a powering voltage of 24 VDC makes instrumentation circuits practically hazard-free.

Since dynamic range is important in instrumentation and

10-50 mA has more range available than 4-20 mA, why has 4-20 mA become the most used and not 10-50 mA? To answer that we will look at some electrical implications of each. Whether we use analog meters or digital systems, both ultimately need to use voltage as the measurement. Analog meters measure current by measuring the voltage across a shunt resistor. Ohms law applies, whereby power equals the current squared multiplied by the resistance ($P=I^2R$) and voltage equals current multiplied by resistance ($V=IR$).

If either system used a meter or digital system with a full-scale input voltage of 5.0 volts DC, we would have to convert the current to a voltage of 5.0 volts. Applying Ohms law results in a resistor of 250 ohms for a 20 mA loop and one of 100 ohms for a 50 mA loop. However, the power dissipation in the resistors is 0.1 watt for the 250 ohm resistor and 0.25 watt for the 100 ohm resistor. The 250 ohm resistor used for the 4-20 mA loop could be a ¼ watt resistor, but the 100 ohm one used for the 10-50 mA loop would have to be a 1 watt resistor. This is because resistors used in circuits should be rated to dissipate more than twice the expected maximum power load and the 10-50 mA loop load resistor would produce more heat. In addition, the power supply for the 10-50 mA loop sensors would have to produce over twice the current as one for a 4-20 mA loop system.

For all of the above reasons the 4-20 mA current loop has become the "de facto" standard for industrial current loop sensors. It is not a standard that was dictated by any organization. It has developed over time because many users felt it provided the best solution and optimized instrument cost and installation. The use of 24 VDC for loop powering resulted from practical as well as safety and hazard considerations.

International Standards Organization (ISO) 10816-1:1995(E)

The International Standards Organization has prepared ISO10816-1:1995(E) "Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts." It is a result of the many years of practical experience by machinery vibration personnel. ISO 10816-1 only addresses the measurement of vibration on the external case of machinery.

ISO10816-1 is a successor to other standards that existed in the past such as ISO 2372 and VDI 2056. All of these standards rely on the same general body of experience dealing with the monitoring of rotating machinery. The current standard, ISO10816-1, defines concepts such as vibration evaluation zones, machine size, and machine mounting.

Vibration evaluation zones are used to classify the severity of the vibrations measured on the machine case. Machinery vibrations measurements are usually made using velocity as the criteria for evaluating machine condition. Both theoretical and practical experience have indicated that velocity is the best indicator to use for evaluating the mechanical condition of rotating machinery when making measurements on the external case.
ISO 10816-1:1995(E) – section 5.3.1 states the following:

The following typical evaluation zones are defined to permit a qualitative assessment of the vibration on a given machine and to provide guidelines on possible actions.

Zone A: The vibration of newly commissioned machines would normally fall within this zone.

Zone B: Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

Another way to view this would be to consider the zones as having the following meaning:

Zone A	Good
Zone B	Acceptable
Zone C	Unsatisfactory
Zone D	Unacceptable

Machines are also classified according to size and mounting conditions. Again, practical experience and theory both confirm that smaller machines generally have lower vibration levels. The rotors are lighter and, therefore, produce lower forces of unbalance. Consequently, the vibration limits for these smaller machines are lower than the limits of larger machines.

ISO 10816-1:1995(E) – Annex B states the following:

Class I

Individual parts of engines and machines, integrally connected to the complete machine in its normal operating condition. (Production electrical motors of up to 15 kW are typical of machines in this category.)

Class II

Medium-sized machines (typically electrical motors with 15 kW to 75 kW output) without special foundations, rigidly mounted engines or machines (up to 300 kW) on special foundations.

Class III

Large prime-movers and other large machines with rotating masses mounted on rigid and heavy foundations which are relatively stiff in the direction of vibration measurements.

Class IV

Large prime-movers and other large machines with rotating masses mounted on foundations which are relatively soft in the direction of vibration measurements (for example, turbogenerator sets and gas turbines with outputs greater than 10 MW).

By combining these definitions of evaluation zones and machine classes, ISO 10816-1 sets out a chart of typical boundary zone limits.

Table I – Typical zone boundary limits

Vibration Velocity in/sec. peak (mm/sec. r.m.s.)	Class I < 20 HP	Class II 20 to 100 HP	Class III > 100 HP typ. rigid rotor	Class IV > 100 HP typ. flexible rotor
2.5 (45)				
1.6 (28)			D	D
1.0 (18)	D	D		
0.63 (11.2)				C
0.4 (7.1)			C	
0.25 (4.5)		C		B
0.16 (2.8)	C		B	
0.1 (1.8)		B		
0.063 (1.12)	B			A
0.04 (0.71)			A	
0.025 (0.45)	A	A		
0.016 (0.112)				

The left column lists the vibration levels associated with the zone limits. ISO 10816-1 uses millimeters per second (mm/sec.) in terms of the root mean square (r.m.s.) value for the overall vibration zone boundaries. These are indicated in parentheses. The generally accepted values in terms of inches per second (in/sec.), peak, are listed in the first column. Inches per second, peak, is in common use in the United States for vibration monitoring programs.

The values given in Table I are in terms of overall vibration levels. However, overall vibration levels must be measured using some defined frequency range. ISO 10816-1 also gives some guidance on this as well. ISO 10816-1:1995(E) – section 3.1.1 states the following:

The frequency range of vibration shall be broad band, so that the frequency spectrum of the machine is adequately covered.

The frequency range will depend on the type of machine being considered (e.g. the frequency range necessary to assess the integrity of rolling element bearings should include frequencies higher than those on machines with fluid film bearings only).

Guidelines for instrumentation frequency ranges for specific machine classes will be given in the appropriate parts of ISO 10816.

NOTE 1 In the past, vibration severity was often related to broad-band vibration velocity [mm/s (r.m.s.)] in the range 10 Hz to 1 000 Hz. However, different frequency ranges and measurement quantities may apply for different machine types.

The guideline as to frequency range is predicated on the history of vibration measurement, to some degree. The IRD model 544 vibration pickup was often used in early vibration measurement programs and it is a seismic velocity transducer. It uses a moving coil in a permanent magnetic field to produce a voltage proportional to the velocity of vibration. The stated operating frequency range for the model 544 is 10 Hz to 1,000 Hz at a sensitivity tolerance of ±10%.

Additional Vibration Criteria

Most rotating machinery produces its major vibration component at the shaft turning speed. The shaft turning speed is usually referenced as the “one-times” turning speed or 1X speed. Two-times the turning speed is then called the 2X, three-times the turning speed is 3X and so on.

As an example, a perfectly good motor running unloaded by itself will always have just the 1X vibration present. There are no other frequencies that will be generated (comparable to the running speed) because there are no other flaws to generate frequency components. The 1X, itself, exists because there is no way to totally eliminate residual imbalance in the rotor of the motor. That residual imbalance will always result in a vibration signal at 1X the running speed.

For machines with anti-friction (roller bearings) there should be no looseness in the bearing of a machine in good operating condition. As roller bearings wear they will develop looseness. The bearing looseness combined with the shaft imbalance will result in higher levels of vibration. The components of the vibration will be a higher level of the 1X along with 2X, 3X and other orders that, combined, will result in much higher overall vibration levels. In addition, the vibration energy from the bearing fault frequencies themselves will contribute to the overall vibration levels.

4-20 mA vibration transducers are not designed to provide data to diagnose machine problems. They are designed to allow the measurement of the overall vibration levels and trend them. It is assumed that personnel familiar with the machine will conduct detailed problem analysis. Vibration analysts can provide the detailed analysis necessary to diagnose specific machine problems when the trend of the overall vibration indicates a potential mechanical problem. Millwrights and mechanics familiar with the machine may also be able to analyze the cause of increasing vibration because of their knowledge of that machine's history and maintenance.

Machines with high average vibration

What can we do about machines that always run at higher levels than proscribed by the ISO standard?

The evaluation zones boundaries defined in the ISO standard increase by a factor of 2.5 for each zone. The transition from the upper level of zone A to the upper level of zone B is related by a factor of 2.5. So, for example, a Class III machine is considered "good" if the overall vibration remains below 0.1 Inches Per Second (IPS) peak. The transition levels are: 0.1 IPS "good" to "acceptable", 0.25 IPS "acceptable" to "unsatisfactory", 0.63 IPS "unsatisfactory" to "unacceptable."

While the ISO 10816-1 standard provides good guidance, some users may not wish to set limits based on these bands and machine classes. Also, it is possible that some equipment already runs at levels considered, by the ISO standard, to be excessive. This is sometimes the case with cooling tower fan units since the gearbox might not be rigidly supported. The lack of rigid support will allow a higher case vibration level than "normal" for that size of machine. This will happen when the support structure is adequately sized to support the weight of the gearbox, but not adequate to restrain the gearbox from "swaying" due to blade imbalance. In other words, the blade imbalance causes the gearbox to "rock" back and forth, albeit on a small enough scale that intervention is not required.

One concept that needs to be understood is that of a "baseline" level of vibration. Machines that are apparently identical will, often, run at different vibration levels. Even when machines are well balanced, properly aligned, and installed correctly their vibration levels will all be different. Sometimes that difference will be a factor of two or three times different. Vibration analysis professionals are all familiar with this phenomenon. The vibration of every machine can be trended to develop a "baseline" of the normal vibration level for that particular machine. This "baseline" level of vibration will be considered valid if all maintenance personnel agree that the machine is running within its normal parameters during the time period when the baseline vibration is developed.

In these, and other cases, where the ISO guidelines are not adequate, the user is left to try to determine what levels to set for limits. This is where the knowledge of the zone boundary relationships can help. Using the zone "width" of a 2.5 multiplier as a guide, the user can establish limits that will help determine when vibration has changed enough to merit attention or action.

As an example, let's consider the situation where an item of Class II equipment is found to have a "baseline" vibration level of 0.2 IPS. The reason for the higher than normal level may be because of installation variations or mechanical support issues, but in this example we will assume that the equipment has been running at this level of vibration for many years. No one wants to shut down this machine when its vibration reaches 0.4 IPS. The vibration level has doubled, but that is not unusual or dangerous in most cases. So where should the limit be drawn concerning tolerable vibration levels?

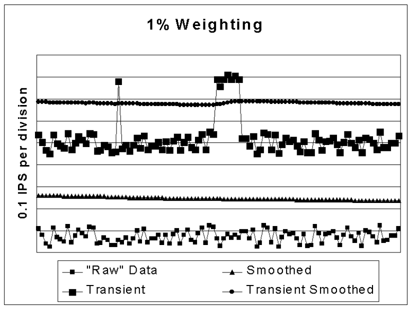
Using the zone width multiplier outlined above as a guide, it can be seen that an increase in the overall vibration by a factor of 3, or more, would indicate that a machine should receive attention. This means that the Class II machine normally running at a vibration level of 0.2 IPS would be considered to have a problem requiring serious investigation when the vibration level reaches 0.6 IPS. However, it is still important to exercise common sense and good judgement when setting limits for vibration.

Nuisance Alarms

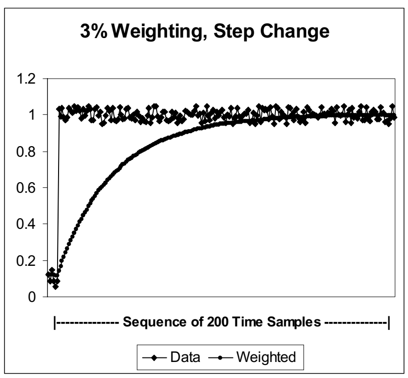
Users of 4-20 mA vibration sensors are often bothered by so-call nuisance alarms. These are situations where, for one reason or another, the system will record a sudden high level of vibration. These could occur because of disturbances in the shielding and grounding system or operating events. For example, a forklift truck driving by the equipment and causing the floor to vibrate would be recorded as an increase in vibration and may be very high for a short time.

Averaging the vibration readings would be one way to minimize these transient levels, however, it is not always practical to maintain a record of a large number of previous readings to develop an average. Another method would be to simply weight the new data values by a constant percentage. For example, multiply the previous data value by 0.99, multiply the new data value by 0.01, then add the two values. This can be referred to as a 1% weighting. This technique would keep transients from causing an alarm, but new vibration levels would be fully achieved within 500 readings.

The illustration shown to the right here, demonstrates how this would affect the data trend. The lower two plot lines show the effect of 1% weighting on relatively lively data, but with no specific process transients. The upper two plots show the effect of a single "wild point" and then the effect of six consecutive "wild points" in the data.

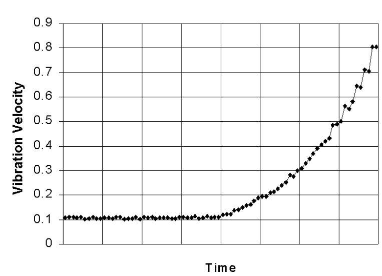


If a faster convergence to the new level is desired, simply adjust the "weighting" percentage. A 3% weighting factor would converge by 100 readings, as can be seen in the lower illustration to the right.



Rate of Vibration Increase

The ISO 10816-1 standard concerns itself with absolute levels of vibration readings. As the previous section illustrated, there are some machines that do not fall "nicely" into the guidelines of the ISO standard. The standard also does not concern itself with the rate of increase of vibration, only the overall level. Trending the rate of increase in vibration can also be a useful measure of machine condition.



When machines have mechanical problems that result in increasing vibration, the vibration will increase as the mechanical fault progresses toward failure. Observing the rate of increase over a brief period of time it is possible to "predict" when the vibration would be expected to exceed the maximum permissible level of vibration for that class of machine. The Programmable Logic Controller (PLC) or Distributed Control System (DCS) can be programmed to perform recursive curve-fitting algorithms, however it is not generally necessary.

When the overall vibration of a machine reaches a level that is double the "baseline" vibration (this can be thought of as a 'trip' point), the overall vibration then bears trending for a rate of increase. The time the vibration takes to go from double the baseline to triple the baseline, an increase of an additional 50%, becomes the time to watch. It has already been established that a level of three times the baseline vibration means a machine needs attention. By trending the rate of increase in vibration as the level increases toward the "three times" the baseline vibration, the user is in a position to judge the seriousness of the vibration.

ISO 10816-1 already defines the increase necessary to go from the upper limit of "good" to the lower limit of "unacceptable" as an increase by a factor of about "six times." When the overall vibration reaches a level "three times" that of the baseline while continuing to increase, and if the vibration increased from "two times" the baseline to "three times" the baseline in less than a month, then it can reasonably be assumed that the machine is in need of immediate attention. The amount of time it takes a machine to get from "two times" the baseline vibration to "three times" the baseline vibration can be multiplied by two to arrive at one estimate as to when the machine should be taken out of service to avoid a catastrophic failure.

This analytical discussion of trends and rates of increase should not be a substitute for common sense and good judgement. Plant personnel charged with operating and maintaining machinery are the people who know best what constitutes faulty machinery. The PC420V-series transducers are designed to allow plant personnel the capability to monitor machines for overall vibration. Setting limits for levels of vibration and rates of increase can refine this automated monitoring task.

Selecting a PC420V-series Velocity Transducer Full Scale Range

So far this guide has discussed the ISO standard, vibration levels and vibration rates. With this background in mind, the user can select a PC420V-series velocity transducer with an appropriate full-scale range. Ideally the user should be able to answer the following three questions.

What is the normal overall vibration level of the machine? This is important so that the transducer used will be able to give a reliable reading of the normal vibration level with enough resolution to determine minor variations in the normal vibration levels. The transducer should be selected such that the normal levels of vibration fall within the region of 10% to 20% of the full-scale range. For example, a machine that has a normal overall vibration velocity of 0.15 inches per second (IPS), peak, might be monitored best with a transducer having a full-scale range of 1.0 IPS peak.

What is the limit for unacceptable vibration? If the manufacturer of the machinery has set specified limits for the machine's vibration, those can be used as a guide to selecting the proper range for a PC420-series velocity transducer. When the manufacturer has not specified limits, the ISO standard can be used as a guide. For example, a 200 HP motor with a rigid rotor would have an unacceptable vibration at 0.63 IPS peak.

Is over-range capability for trending desired? The standard ranges available in the PC420V-series will allow for some over-range capability, but some users may wish to have more. A 50 HP motor may be driving a fan that has a history of blades cracking. When cracked, the fan may exhibit vibration of 1 to 2 IPS. Here it may be desirable to use a transducer with a full-scale range of 2.0 IPS to accommodate the potential for the fan imbalance when cracked blades occur.

If the user does not have answers to any or all of these questions, the ISO standard can be of assistance in determining the best full-scale range PC420V-series transducer. Smaller machines (under 100 HP) can likely be monitored using a PC420V-series unit with a full scale of 0.5 IPS since that would suffice to cover most monitoring and trending needs. Machines over 100 HP would usually be best monitored using the PC420V-series unit with a full-scale range of 1.0 IPS peak. Machines with a history of very high vibration associated with certain machine faults, such as fans or compressors, might best be monitored with a PC420V-series with a 2.0 IPS peak full scale range.

Measurement Locations

A general statement can be made as to vibration measurement locations. "Make vibration measurements at all locations where the rotating components interface to the machine frame." Additional measurements at the attachment mounting locations may be useful on machines that present particular problems related to structural response. Examples would be resonance in the structural support system for a rotating machine or resonance in the pipe system attached to a pump.

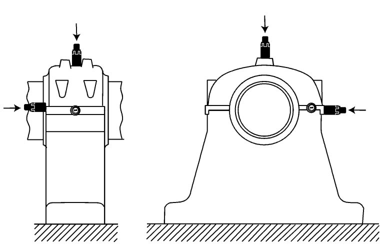
General guidance as to mounting locations for vibration sensors is contained in ISO 10816-1:1995 Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts, Part 1: General Guidelines. Here is the guidance contained in section 3.2 Measuring Positions:

Measurements should be taken on the bearings, bearing support housing, or other structural parts which significantly respond to the dynamic forces and characterize the overall vibration of the machine.

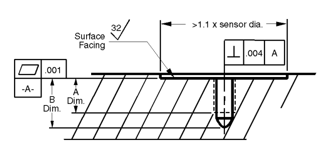
To define the vibrational behavior at each measuring position, it is necessary to take measurements in three mutually perpendicular directions. The full complement of measurements (at each support and in three mutually perpendicular directions) is generally only required for acceptance testing. The requirement for operational monitoring is usually met by performing one or both measurements in the radial direction (i.e. normally in the horizontal-transverse and/or vertical directions). These can be supplemented by a measurement of axial vibration. The latter is normally of prime significance at thrust bearing locations where direct axial dynamic forces are transmitted.

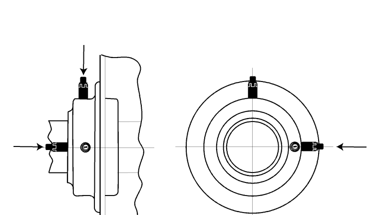
This guidance basically states that a complete set of measurements for rotating shaft vibration consists of two radial readings at a bearing position in directions 90° apart and an axial direction reading. This is also the same advice given by most manufacturers of vibration analysis equipment and purveyors of vibration training courses.

The illustrations presented here show some examples of mounting locations to achieve a full complement of measurements at each bearing position if a user were to mount permanent accelerometers for each measurement position. Also illustrated is the surface preparation necessary to properly mount industrial transducers on machines. The spot-facing and pilot hole drilling can be accomplished in the same operation by using the Wilcoxon spot-face tool, ST101. It will face off a 1.25 inch diameter spot while drilling the pilot hole for a ¼-28 tap. More information on mounting industrial accelerometers is



Pedestal Bearings



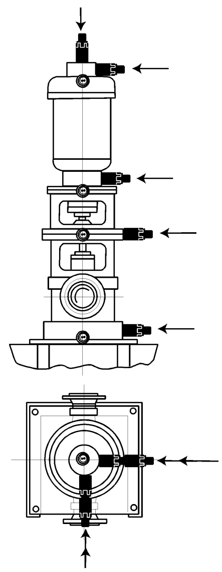


Housing-type Bearings

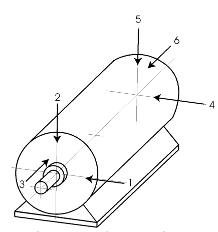
available in Wilcoxon Research, Inc. Technical Note 21, Mounting Considerations, available for download in an Adobe™ portable data format (pdf) file from www.wilcoxon.com.

One question often asked is, “Do I really need to install accelerometers in all three axes at each bearing location?” The answer is, generally, “No.” Even the ISO document admits that only one or two measurements at a bearing position are necessary for operational needs.

On the illustration for a pedestal bearing the bearing support structure has the highest stiffness in the vertical direction. Consequently, if a user wishes to measure the highest levels of vibration experienced on this bearing, the horizontal (radial) direction will yield the highest reading since the horizontal direction has lower stiffness than the vertical. In general, one sensor should be used at every bearing position and it should be mounted in the direction of least support stiffness.


Vertical Machines

For vertically mounted equipment, such as vertical pumps, any horizontal direction would seem to present equal stiffness and, hence, equal vibration levels. However, equipment support structures may, in fact, have higher stiffness in one direction versus another. In that case the sensor should be mounted in the direction of least stiffness to measure the highest vibration levels.



Small Electrical Machines

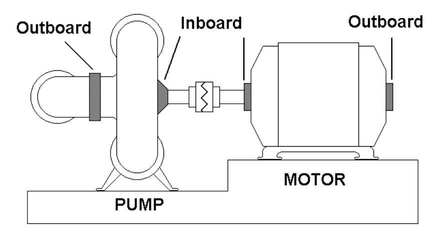
Another question arises as to axial measurements. If measurements are being taken at each bearing position, are axial measurements at all necessary? While not absolutely necessary, at least one axial measurement should be taken at the bearing position where there is a thrust bearing or a bearing that can act to accept an axial load. Some vibration problems will exhibit symptoms better in the axial direction than in the radial direction. This vibration energy can be measured best at the bearing location where axial loading will transmit to the bearing case.

Some additional guidance as to monitoring locations will come from the actual maintenance history of the machine. If the machine, or similar types, have a history of some particular fault mode, that fault mode should be used for guidance as to where to mount vibration sensors. For example, if a particular model of pump usually has problems with the bearing at the driven end of the pump, it would be a good idea to monitor the driven end of the pump in the radial direction. If a user were to only have the ability to mount one permanent sensor, then the user should tend toward mounting that one sensor in a location most likely to indicate the most likely failure mode of the pump.

Two of the greatest problems facing the vibration analyst are how many sensors to mount and where to place them. As a general rule, if only one sensor can be permanently mounted, it should be placed at the thrust bearing since faulty bearings will transmit vibrations in the axial as well as radial directions. While the vibration energy is lower in the axial direction, it is still available for analysis.

So where do you put additional sensors? What is the optimum number of sensors to use? Since the axial reading will be on one piece of equipment, the second sensor should be mounted in the radial direction on the other piece of equipment. For a typical equipment set of one driver and one driven element (i.e. motor driving a pump) there will usually be four total bearings with one of them acting as a thrust bearing. This means a total of five sensors would be the usual optimum number of sensors.

For example, look at the motor-pump unit in the illustration. There are four bearing positions, two on the pump and two on the motor. The inboard pump bearing serves the function of taking up axial thrust as well as radial force. In this case the optimum number of sensors would be five (5). One in the horizontal position at each bearing (4) and one in the axial direction at the inboard pump bearing (1) for the total of five (5).



Summary

Vibration transmitters offer industrial plants the opportunity to include machinery vibration with other operating parameters measured by PLC and DCS systems. Unlike flow, pressure, or temperature, however, vibration is not usually related directly to the production process. Vibrating screens and mixers are exceptions to that statement, their operation must be at a certain level or the process can be directly affected.

Plant personnel must decide what limits to place on vibration. Often, data is available from historical vibration records to indicate the levels of vibration that are acceptable and unacceptable. In the absence of such historical guidance ISO 10816 can provide useful information to aid in selecting proper settings for vibration limits. This guide adds some additional information to aid in guiding users in their quest for vibration limits. Here we have introduced the concepts of baselining, rate of increase, and data weighting. Using ISO 10816 as a guide we have expanded on the number of vibration sensors to use and where to locate them on machinery.

However, it is primarily the responsibility of the plant maintenance personnel to determine whether to monitor vibration, where to locate sensors, what is an acceptable level of vibration, and when to institute corrective mainenance. This guide is designed to provide some additional data to aid in those decisions. It is not intended to replace the knowledge of experienced maintenance personnel. Operating and maintenance personnel are the people who generally know their machinery the best.

In any situation involving vibration monitoring the best guidance is to use common sense and good judgement.