VIBRATION MONITORING SYSTEM OF STEAM TURBINE

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What is Vibration

Vibration is static and dynamic imbalance of equipment.Vibration is the oscillation, or moving back and forth of an object. The word vibrations consciously or unconsciously use it as a measure of how well things are running in a process plant. For vibration to get start it takes some effort, either external or internal to get vibration going, some input of energy through an applied force. Once we have put energy into the system to make it vibrate, how do we characterize the vibration? Amplitude and frequency are common characteristics. When we deal with several vibration phase also will becomes important.

The force we apply to vibrate directly affects the vibration. The more force we apply, the greater the vibration amplitude. But what acts to limit the vibration? As we make stiffer, like a spring, the amplitude of vibration decreases. We can say that 3 physical characteristics control the vibration.

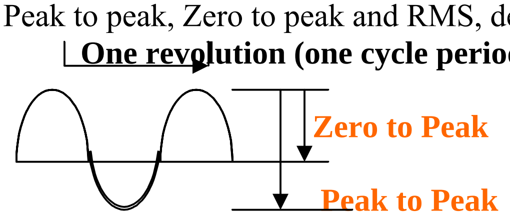
- Mass
- Stiffness (spring)
- Damping

Vibration measurement

The principle characteristics of the vibration signal that we measure are **AMPLITUDE, FREQUENCY AND PHASE.**

Amplitude

Amplitude is a measure of how severe the vibration is and can be expressed in 3 different ways: Peak to peak, Zero to peak and RMS, depending on what signal we are measuring.

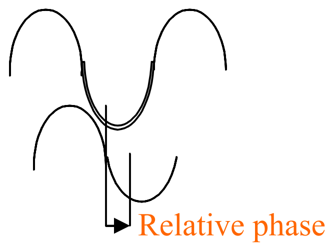


Vibration is measured either in terms of displacement, velocity or acceleration. **Vibration displacement** is always measured as **Peak to Peak,** a measure of the total excursion of the rotor or machine casing in **MILS or MICROMETERS**. Vibration velocity and Acceleration are measured as **Zero to Peak or RMS**. Units used are "inches per second" or "millimeters per second" for velocity or in terms of "G" or "meters per second per second" for acceleration.

Frequency

Frequency is a measure of how fast a body is vibrating and is used to identify the source of vibration. Normally Frequency is expressed in shaft rotative speed. If a vibration is at the same frequency as the shaft speed, this will be 1X or 1 time shaft speed. If it is twice it is 2X. Also the frequency may be expressed in cycles per second or Hertz, or in cycles per minute. The period of vibration is measured in seconds and the reciprocal calculated will give in Hertz.

Phase



Phase is a simple timing relationship between 2 events which may be 2 vibration signals for Relative Phase measurements or a vibration signal and a keyphasor reference signal for Absolute measurements. Both these are important vibration signal properties.

To measure the relative phase between 2 vibration signals, both signals should be at the same frequency and should be in the same units ie. Both displacements, both velocity or both acceleration. Both signals may be taken as the reference and the relative phase is expressed as an angle between O^o and 180^o leading or lagging.

Shape or Form

The shape or form can be viewed by using the oscilloscope. The shape can be viewed by combining the signals from the vertical and horizontal proximity transducers. For most machines this will be either circle for uniform mechanical impedance or an ellipse with low eccentricity where the mechanical impedance is not uniform in all directions. The shape can be a good indicator of non uniform mechanical impedance, preloads such as misalignment and rotor to stator rubbing.

Reference frame for vibration measurement

Each vibration transducer measures the vibration in a different way, either a relative measurement or an absolute measurement.

Relative measurement

The proximity transducer system measures the motion of the shaft relative to the transducer tip. As the transducer is located close to the bearing (less than 6") the proximity probe can be considered to measure the motion of the shaft relative to the bearing. This gives an indication of the amount of available clearance taken up by the shaft motion. If the transducer mounting is in motion due to vibration, this will result in an output from the transducer which will appear as if the shaft is moving.

If the shaft and the transducer mounting are moving together in phase, the resultant output from the probe will be zero as if there is no shaft vibration. Great care in mounting should be taken to ensure that this situation will not arise.

Absolute measurement

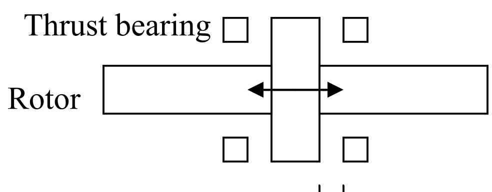
Absolute measurement or seismic measurements are made using either a velocity or acceleration transducer mounted on the bearing housing or machine casing. Absolute measurements are needed where casing or housing motion is significant. The velocity or

acceleration transducer measures motion relative to free space, with the coil as reference for the velocity transducer and the mass as reference for the acceleration transducer.
Shaft absolute measurement is made by measuring the shaft relative displacement using a proximity probe and the bearing displacement using either a velocity probe or accelerometer.

The velocity or acceleration measurement are integrated (or double integrated in the case of accelerometer) and then subtracted from the shaft relative displacement.

Only in rare cases is the shaft absolute displacement required or machine measurement, shaft relative displacement usually provides sufficient information.

Position measurement
Axial Thrust position
This is a measurement of the rotor within the thrust bearing clearance. The measurement is usually made using two proximity probe mounted in the thrust bearing observing the thrust collar.

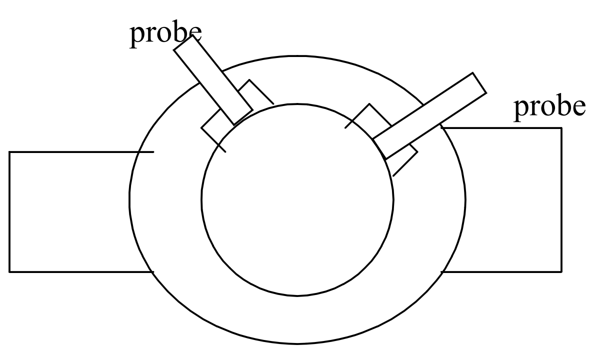


Thrust position measurement

If this is not practical, the probes may be mounted at some location close to the bearing observing the shaft end or a specially fitted collar. To ensure reliable measurements, axial thrust position should always be made using 2 transducers.

The signal from the transducers are monitored using a dual voting thrust position monitor which looks at both the signals and compares them with the alarm levels. If either signal exceeds the first preset alarm value the alarm will be indicated and relay will change state. If the levels increase to the second preset level the monitor will indicate the alarm but unless both this signals exceeds this value the relay will not change its state.

Radial Position



Radial position of the shaft within the bearing clearance can be measured using the Dc signal installed from the proximity probe.

The DC signal is measured when the machine is at rest with the shaft sitting at the bottom of the bearing and again when the machine is running.

With the shaft supported on its oil film, the change in DC voltage measured can be used to calculate the new position of the shaft center line. This can be a very important measurement to determine the condition of the shaft alignment and also to indicate any bearing wear which might be occurring. The signal needed to make these measurement are available at the front panel of the monitors.

How to calibration check of vibration Probe, extension cable and vibration monitor:

- Physical check of vibration probe and extension cable for any damages, if it is please replaced with same one.
- Check resistance of vibration probe and continuity of extension cable it should be 5 to 9Ω and 5 to 20 Ω
- Use below equation and get reading for calibration of vibration probe.

1 mils = 0.001 inches
1 mils = 0.0254 mm
1 mils = 25.4 micron
1 mils = 200 mvdc

$$\text{RMS VALUE} = \frac{\text{Mils} \times \text{Scale Factor}}{2\sqrt{2}} = \text{(VAC)}$$

$$\text{VDC} = \text{Mils} \times \text{Scale Factor}$$

- Connect test equipment.
- Adjust the spindle micrometer on the TK-3 test and calibration kit shown 0.51 mm (20 mils) (0.0254mm=1mils).
- Insert the probe in to the TK-3 probe holder adjust the probe in the holder until the digital multimeter shows -3.00 ±0.10 VDC.
- Adjust the micrometer to 0.20mm (8 mils) indication and the back it out again to the 0.25mm (10 mils) indication backless in the micrometer forced the o/p voltage and record it.
- Increase the gap in 0.25 (10mils) increment by adjusting the micrometer record the voltage indication at each increment.
- For each gap increment subtract the voltage at the high gap from the voltage at the low gap divide the result by in a system incremental scale factor of 7.87 ±0.79 v/mm (200 mv ±20 mv/mils).
- Subtract the 0.25 mm (10 mils) voltage (-5 vdc) from the 2.28 mm (90 mils) (11 vdc) and divided by 2.03mm (80 mils). The result should ina system average scale factor (ASF) of 7.87 ±0.43 v/mm (200 mv ±11 mv/mils).
- If the incremental scale factor or the average scale factor of the system is out of tolerance (refer to the specifications in appendix C).

Differential measurement

For large steam turbines with long shaft systems, an additional axial position measurement may be required to measure the position of the rotor at a location away from the machine thrust bearing.

In all machines the thrust bearing is rigidly fixed to the machine foundation and the casings are free to move due to thermal expansion in an axial direction. For large machines the thermal expansion of the rotor will not be the same as the expansion of the casing. The differential expansion measurement is to measure this difference and ensure that the rotor does not touch the stationary parts.

Shaft eccentricity
This is the bow or bend in a machine shaft and is measured at very low shaft speed in the order of a few revolutions per minute.

Ideally the proximity transducer is mounted some distance away from the bearing so that the maximum deflection will be detected when the machine is run at slow roll speed. The measurement made by the transducer is then not due to dynamic motion but is a purely measure of the shaft bow.

TRANSDUCER OPERATION AND APPLICATION

We measure one of the 3 characteristics of vibration.

- Displacement (how far something is moving)
- Velocity (how fast the displacement is changing)
- Acceleration (how fast the velocity is changing)

All these are related and can electronically convert from one to another by using integrator. So why do we have different transducers to measure vibration ?

We are using 3 types of transducers.

Proximity (displacement) transducer system :-
This covers a broad term category of techniques for measuring displacement. This includes Radar, laser, capacitance and eddy current methods. Most commonly used is eddy current method even though it is a non contact type measurement.

Velocity transducer system
Until recently the coil and the magnet design of the velocity transducer has been the standard way of measuring the velocity characteristics.

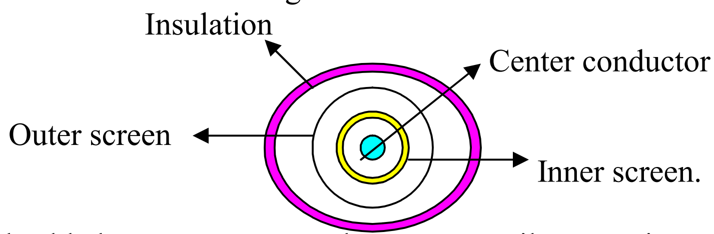
Acceleration transducer system
Piezoelectric type of transducer is the one that is used for. The piezoelectric effect describes the voltage that appears across some natural and man made crystals when they are subjected to a force. The acceleration transducer is also the heart of the velomitor, which output a velocity signal. Integrator converts the acceleration signal to velocity.

3500 proximity transducer system
This has 3 parts.

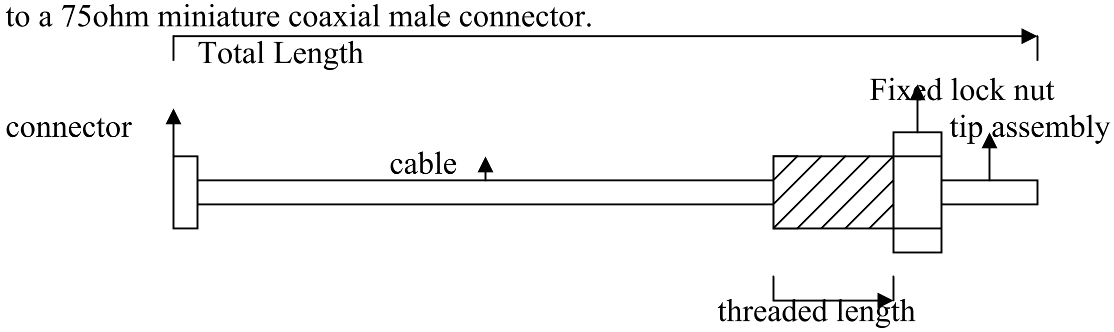
- Probe
- Extension cable

- Proximitor
-

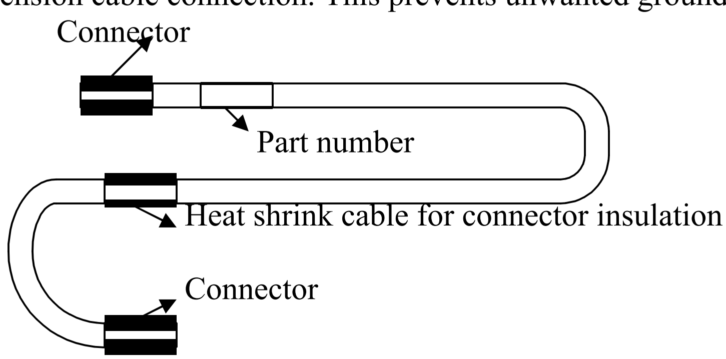
Probe
This part is installed on the machine. It has a tip assembly, made of generic version of RYTON (thermoplastic), that threads into a stainless steel case. The tip assembly is 8mm in diameter and contains a coil whose ends terminate to a 75ohm miniature tri axial cable that exits the stainless steel casing.



The tri axial cable has one center conductor, as a coil connection, and two screens. The inner screen is a coil connection and the outer screen not connected. This prevents unwanted grounding of one side of the coil if the cable is damaged. The cable terminates to a 75ohm miniature coaxial male connector.



Extension Cable
This is the part that connects to the probe and allows you to reach a convenient junction box. It has a length of tri axial cable identical to that used on the probe. One end of the cable terminates to a 75ohm miniature co axial female connector for connection to the probe. The other end terminates to a 75ohm miniature coaxial male connector for connection to the proximitor.
A piece of heat shrink sleeve is available on the cable to be slid over the probe to the extension cable connection. This prevents unwanted grounding of one side of the coil.



Proximitor
This is the part that contains the electronics and is usually mounted in a junction box. It has a die cast aluminum case with a powder gray coat that resists oils, solvents and chemicals. A 75ohm miniature co axial female connector is chassis mounted through the

casing for the connection to the extension cable. A terminal strip is also case mounted for supplying voltage to and taking signals from the proximitor. The base has an isolation plate mounted on it that will prevent unwanted grounding of one side of the probe coil. The circuit board mounted electronics are resin encapsulated with in the casing.
Part no. ex :- 330100-90-00
90 :- 9 meters total length (probe with integral cable and extension cable)
00 :- hazardous area approval not required.

This 9 meter total length is **Electrical Lengths** and not physical length (although they will be close). This is because the probe and extension cables are trimmed in length to electrically match proximitors.

System Operation
The proximitor is an electronic device and has 2 basic functions.

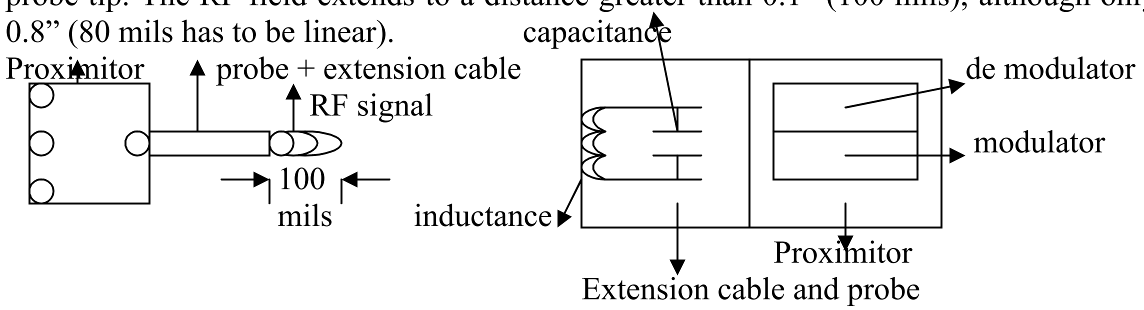
- Generates a radio frequency (RF) signal using an oscillator
- Conditions the RF signal to extract usable data using a demodulator circuit

To do this it needs a –17.5 to –26Vdc supply voltage connected between VT and COM terminals.

Once the proximitors oscillator has power it will generate an RF signal at a specific frequency. This frequency is depend on the Inductance of the Probe coil and the Capacitance of the extension and probe cables.

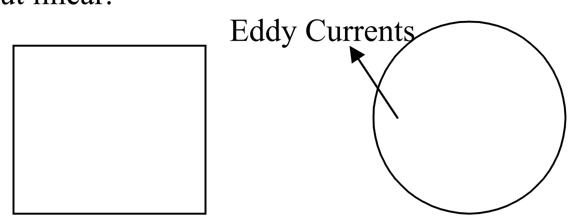
The RF signal frequency will be within a range from 500Khz to 2 Mhz. **Having a mismatched transducer system (cable length too long or too short) will change the RF signal frequency and result in an incorrect proximitor output.**

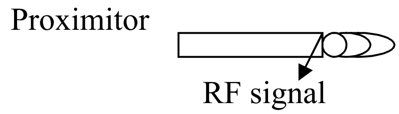
The RF signal is transmitted from the probe coil which creates an RF field around the probe tip. The RF field extends to a distance greater than 0.1” (100 mils), although only 0.8” (80 mils has to be linear).



When conductive material is present in the RF field **Eddy Currents** flow in the surface of that material. The penetration depth of this signal depends on the material conductivity and permeability. 4140 steel penetration is 0.003”(3 mils).

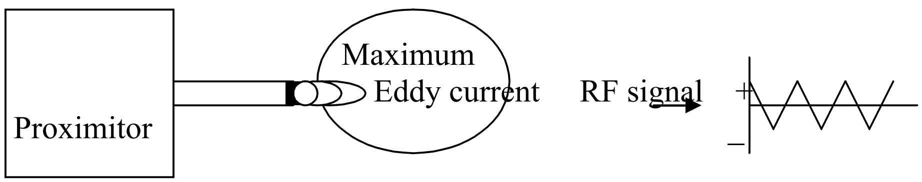
If the material to be plated, the plating must be done to a minimum of penetration depth. This ensures that the eddy currents always penetrate the plating material which keeps the system output linear.





Once the probe is close enough to cause eddy currents to flow in a conductive material the RF signal is affected in 2 ways.

- The amplitude is at a **minimum** when distance (Gap) between probe and material (**Target**) is at a **minimum**. **Maximum** eddy current flow occurs.



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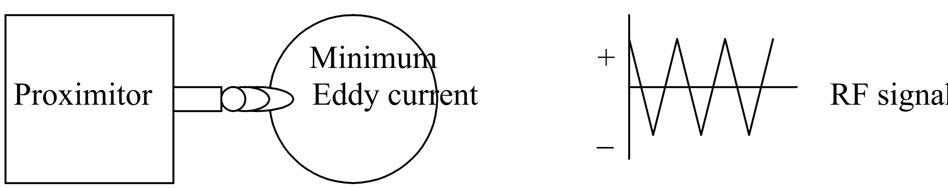
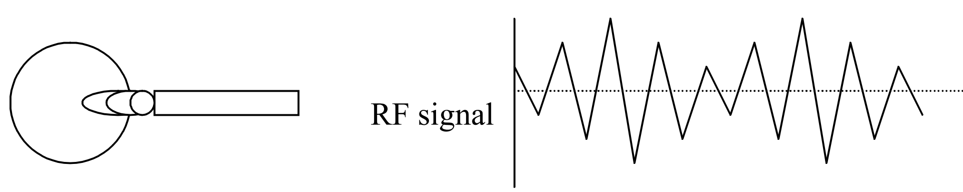
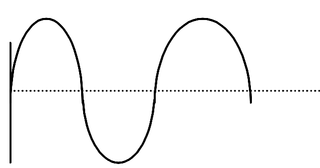


If the target is moving slowly within the RF field, the signal Amplitude Increases or Decreases slowly. If the target is moving rapidly within the RF field, the signal amplitude increases or decreases rapidly. Rapid movement of the target causes the RF signal to modulate.



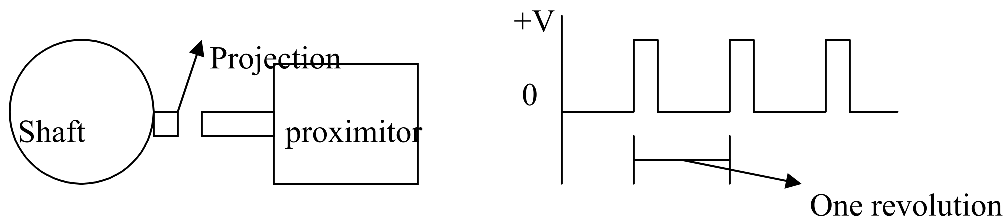
The demodulator circuit deals with a slow or fast changing signal amplitude in the same way. If the target is moving slowly (signal amplitude and gap not changing), the proximitors output is a negative DC voltage shown by a dashed line. If the target is moving fast (signal amplitude and gap changing fast) the proximitor output is a varying DC. Voltage (a.c) shown by a sine wave. If the probe sees a vibration, the proximitor will have d.c component and a.c component. The system frequency response is from 0hz to 10Khz.



Applications

A proximity system have many uses in monitoring the behavior of a machines shaft (target). The two most common being Vibration(radial movement) and Thrust (axial movement).

Another common use is the Once per revolution marker on a machine shaft. Bently neveda uses Key phasor. It is achieved by mounting the probe in such a way that it sees a notch or projection on the shaft and produces a voltage change in pulsed form.



The keyphasor is a very useful tool when diagnosing machinery problems. The generated pulse at a minimum can be used to measure machine speed.

Performance verification

The proximitor is designed to give known output voltage changes equal to known gap changes. This is called a **Scale Factor.** For 3500 probe the scale factor is 200mv/mil. The scale factor are linear for a minimum of 80mils within the systems linear range. A tolerance of +/- 6.5% is allowed for SF (187mv/mil to 213 mv/mil).

If the scale factor changes beyond this limit it may be

- The supply to proximitor is not –17.5 to –26V dc.
- Probe, extension cable and proximitor is mismatched in electrical length.
- The proximitor is calibrated for a different target material than the one used.

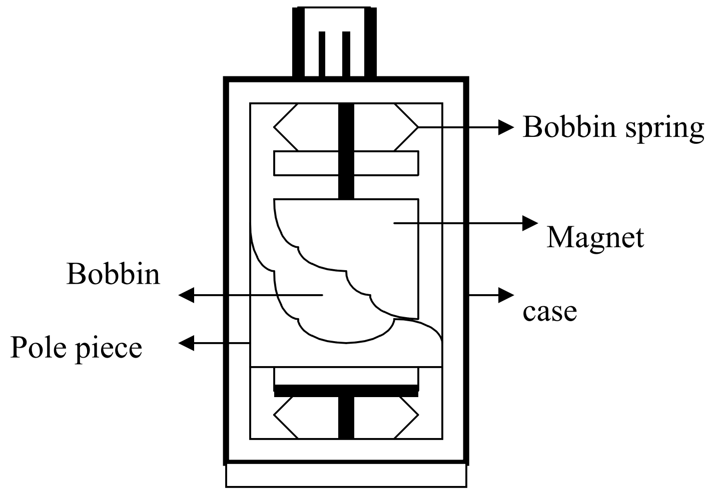
Advantages and Trade offs

	Advantages	Trade offs
1	Measures vibration and position of shaft (response from 0 to 10 kHz)	Sensitive to material properties and service conditions
2	Measures direct shaft motion with out contact	Internal installation requires planning, may require drilling through case.
3	Provides speed and keyphasor reference signal	High frequency vibration usually results in low displacement levels
4	Long term reliability	
5	Provides slow roll information	
6	Simple calibration check	

Velocity transducer system

Velocity transducer system measures how fast the displacement is changing.

Typical applications are external to the machine. Bearing housing, casing, foundation, piping, supports etc.



The traditional velocity system consists of a coil and a magnet, either of which (but not both) may be mounted on springs. As they move relative to each other, the magnetic flux cuts the coil and generates a voltage. The output is a function of the rate of change of flux, or relative velocity of the coil and magnet. But which component moves? Is it one on the spring? Or the one attached to the case?

Think of a weight on a spring, with you on the other end of the spring. If you pull slowly, then the weight also will move. But if you move quickly, the inertia of the weight will prevent it from moving as quickly as you do. If you move very quickly, back and forth (vibrate), the weight won’t move at all. That makes the weight an inertial reference, similar to what a guidance system uses, and it becomes an absolute reference for the velocity measurement. So, whereas the proximity system measures in a relative reference frame, the velocity transducer measures in an absolute reference frame. In the velocity transducer system the spring mounted bobbin is the inertial reference.

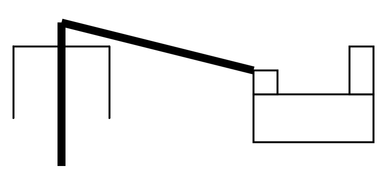
Velocity in/s peak = V pk/sensitivity

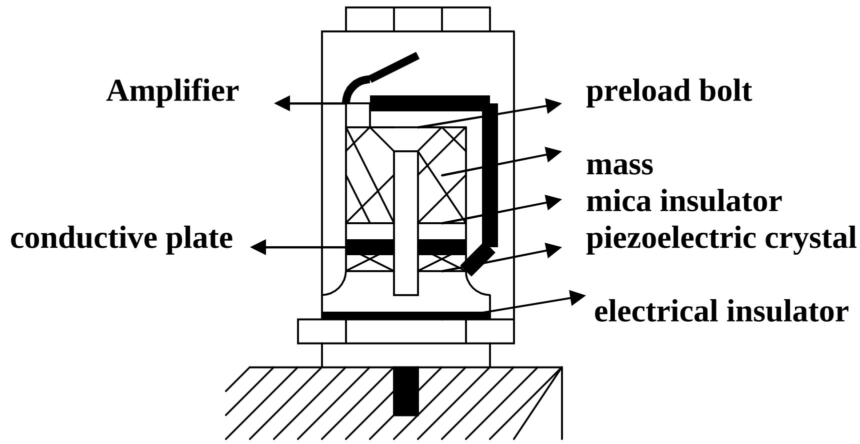
Usually used sensitivity = 500 mv/in/s pk.

Mounting orientation is very critical for velocity transducer. To check the calibration a device called shaker table is used. But normally the transducer is sent to a metrology department.

	Advantages	Trade offs
1	Easy bearing house installation	Complete calibration check requires shaker table
2	Good for mid- frequency bearing housing installation	Poor reliability
3		Sensitive to mounting orientation
4		Sensitive to cross axis vibration
5		Can not measure direct shaft vibration without contact.
6		No slow roll information.

Acceleration transducer system





Mass is inertial reference.

The crystal in the acceleration transducer is sandwiched between 2 masses. One is the case which is attached to the machine and the other is mounted on a spring. The spring consists of the crystal and the preload bolt. The mass applies force to the crystal as the crystal vibrates, and that force causes electrons to collect producing a voltage.
Force = mass * acceleration
When the mass is constant the force which in turn the voltage is proportional to the acceleration.
Acceleration pk = V pk/ sensitivity

	Advantages	Trade- off's
1	Easy bearing housing installation	Complete calibration heck requires a shaker table
2	Broad frequency response	Sensitive to mounting method and service condition
3	Long term reliability	Broad frequency response means noisy signal, often needs filtering
4	Good for high frequency casing measurement	Can not measure direct shaft vibration with out contact.
5	High temp. ranges available	

Velomitor transducer system
The velomitor can be used in any application where the standard velocity transducer would be used. Typically for measuring bearing housing, machine casing, foundations, piping , supports etc.

This consists of a piezoelectric ceramic disc clamped between 2 masses. One mass is the case which is attached to the machine and the other is the inertial reference mass, mounted on a spring. The spring is the ceramic disc and preload bolt. The mass applies a force to the crystal as the transducer vibrates, and that force produces a charge on the crystal proportional to the vibration acceleration. The signal pass to an internal circuit which filters out any low frequency components and **integrates** to produce an output proportional to the velocity. The reference frame for the measurement is absolute with the inertia mass as reference.

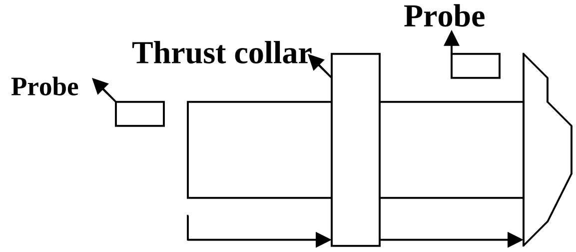
	Advantages	Trade off's
1	Easy bearing housing	Complete calibration requires a shaker table
2	Good mid frequency range bearing housing measurement	Requires a constant current supply.
3	Long term reliability	No slow roll information
4	Higher temperature ranges available.	

Probe installation and pitfalls
Installation considerations
The following points to be considered particularly with proximity probe system.

- Correct and compatible components :- the transducer system, probe and extension cable and proximitor should be matched electrically. This involves checking cable lengths and required system length and target material. It is not permitted to mix 3300, 3500 and 7200 system components.
- Components compatible with application and environment :- ensure that the transducer system to be installed will be able to operate in the machine environment. Check the pressure and temperature of the probe. Check the chemical environment to ensure that the probe will not be damaged. It is also important to ensure that the probe has the right performance characteristics to carry out the required measurement. Check the linear range against the expected movement. Check the probe tip diameter against the target area.
- Inspect parts for damage :- make sure there is no physical damage to the probe or extension cable. Check the probe tip for signs of cracking or chipping caused by contact with moving parts. Check the cable outer sheath for cracks, cuts and abrasions. Check the API connectors to ensure that they are free from any corrosion or contamination.

Probe mounting
As far as possible the probe should be accessible without dismantling the machine or removing the bearing or coupling covers.
If it is not possible probe should be mounted using appropriate blocks or brackets to te bearing or bearing housing. Cables should be clipped and routed to prevent movement. Adequate oil splash seals should be installed to prevent oil leakage.

Axial probe installation



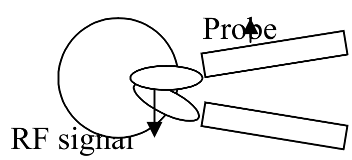
12” max 12” max.

Ideally the probe should be mounted to observe the thrust collar, but where it is not possible the axial thrust probe should be located within 12” of the thrust collar observing an integral part of the rotor such as coupling or shaft end.
Care is needed to ensure that the target area available is large enough for the particular probe to be used.

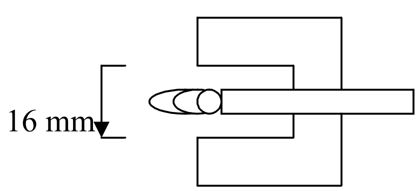
Radial probe installation
Radial vibration probes should be mounted typically within 6” of the bearing, allowing us to monitor shaft motion within the baring clearance.
The support bracket should have a resonant frequency at least 10X the rotative speed to prevent the probe from vibrating.
For externally mounted probes, the probe sleeves should be supported within 8 to 12” of the probe tip to prevent the probe tip from vibrating.

The 2 probes should be located 90o +/- 5o from each other, otherwise errors will be introduced in the measurement particularly shaft center line position.

Pitfalls
A cross talk occurs when 2 probes are mounted too close together so that their RF field interact with each other.
Probe RF frequencies are unlikely to be the same therefore when mixed together a difference frequency is generated. This difference is usually within the normal band of frequencies expected for vibration. Therefore a target may appear vibrating when it is standing still. The minimum distance between probe tips should be minimum 1.6”.



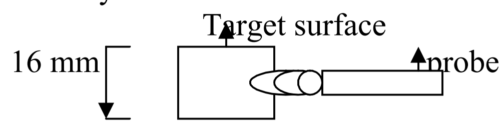
Side view occurs when the probe is mounted in an area that has insufficient side clearance around its tip. Eddy currents will be generated in any conductive material within that area. This results in losses in the system that are not due to the real target.



the minimum mounting area is 2 * tip diameter which for the 8mm probe is 16mm.

Target size must be large enough to make contact with all of the radiated RF field in front of the probe. The minimum target size is 2 * tip diameter(for 8mm probe it is 16mm).

The effect on linear range and SF, with an under sized target, will vary depending on the amount of eddy current created.



Correct target size

Incorrect target size.

Noise

Signal = information + noise.
Information :- data used for analysis
Noise :- information you don't want to deal with.
A change in noise is also an information.

Sources of Noise :-
The major source can be grouped into 3.
Poor installation

- Improper Grounding :- the problem that seems to cause the most trouble is the improper grounding and grounding techniques. This involves not only the transducer and monitor installation, but the instrumentation installation as well. Systems with no grounding pick up a lot of noise from the environment.
  Too many grounds suffer from ground loops which can cause dc offsets and saturation of instrument inputs. An example of ground loop would be an instrument located at a machine connected to a transducer grounded back into the control room. If the instrument receives power local to the machine and instrument common is not isolated from ground, a ground loop is created.
- Poor connections.
- External fields
- Improper mounting

Transducer characteristics electrical and mechanical
A proximity transducer system uses an electromagnetic field radiating from a coil of wire in the transducer tip to generate eddy currents in the surface of the material it is observing. The interaction with the surface and the dependence of the response on surface properties creates the opportunity for noise to occur.

Electrical

- Residual magnetism
- Localized stress concentrations
- Non uniform alloying, plating, heat treatment

Machine

- Surface irregularities
- Rotor bows
- Non concentric rotors

Anything that produces non uniform electrical characteristics or mechanical irregularities in the surface will generate noise.

The residual magnetic fields can be caused by magnetic particle NDT(non destructive testing) and grinding. Stress concentration and work hardening which change the electrical properties of the surface can even be caused by hanging the rotor in a sling. The most important characteristics of this noise is that in almost all cases it is repeatable. The frequency range is from running speed to many multiples of running speed.

In a velocity transducer system the noise problems stem primarily from its moving coil design. Coupling of transverse (cross) axis vibration, loose particles between the moving parts, and warping of the coil or case all produce an unpredictable, sometimes stick slip, kind of response. The electrical problems are not much more predictable.

Second electrical noise source is the integrator. The integration process amplifies the low frequency, and lower the frequency greater the amplification. Thus any low frequency noise in the velocity signal becomes prominent when integrated.

Here the noise source is transient in nature. Since the source of the noise can be independent of the machine, the frequency range is well below to well above running speed.

Mechanical

- Transverse axis sensitivity
- Mechanical reliability
- Thermal transients

Electrical

- External magnetic field
- Integration noise

Acceleration transducer system, the mechanical sources of noise tend to start at opposite ends of frequency spectrum. Thermal transients tend to cause low frequency noise, while vibration in the resonance frequency will stress the crystal and can produce false components at other frequencies.

Sensitivity to high frequency vibrations, where even small displacements are associated with high values of acceleration is another source of broadband noise for the acceleration transducer. In the mean time electrical problems produce noise at both high and low frequencies.

The crystal is a high impedance device that requires electronics to match it to the rest of the world. When those electronics are outside the transducer, special low noise cables are recommended. If these cables are not secured, the flexing will produce high frequency noise.

These noises are transient or random in nature.

Mechanical

- Vibration in resonance region
- Thermal transients

Electrical

- Impedance sensitivity
- Cable noise
- Integration noise, especially double integration .

<u>How to reduce noise</u>

Categorize as repeatable or random/ transient. If so the choice for reducing is limited.
If the noise component is repeatable, determine is it short term like thermal bow, gravity bow, or long term, as with a scratch or kink in the shaft.

Document

- The noise at slow roll condition.
- Stopped condition

Reduce

- Filter :- use carefully as it will remove noise and signal in a particular frequency. Ex. Band pass, low pass, high pass, band reject or notch.
- Compensate :- if the noise is repeatable and measurable it can be subtracted from the signa.

<u>3500 Monitoring system introduction.</u>

In 3500 system there 3 basic parts in a rack. The power supply, system monitor and the monitors.

Power supply

This provides regulated power up to 12 monitors and their transducers. It converts 115v AC or 220v AC to –18v or –24v DC. For 3500 and 7200 series proximitors require –24v and 3000 series proximitors require –18v.

The system monitor

It checks the voltage supplies which is vital for the proper system operation. It also controls system OK function. This OK shows that the system's transducers and field wiring are operating within the limits. The system monitor also provides a link between the monitor rack and software products used for data collection using a computer.

Monitors

This tells you whether the transducer system is operating properly (OK), how much is being measured by the transducer (amplitude in the LCD), and whether this is too much (danger or alert).

Programmable options
3500 system provides plug in jumpers for programming to a desired configuration. This configuration is read by a microprocessor.

Alarm time delays
The options available are 0.1,1,3 & 6 seconds. This is the interval between when the input signal amplitude exceeds the alarm set point levels and the actuation of the alarm relay. This avoids mechanical or electrical transients from causing false alarms.

For most vibration monitoring applications 3 seconds delay is recommended. This will minimize false alarms from normal transient vibration or electrical noise sources.

For thrust 1 second delay can minimize damage from thrust failures.

Latching/ non latching
With latching alarms (or OK) manual reset is required to clear the front panel LED and relay even if the measured variable has decreased below set points.

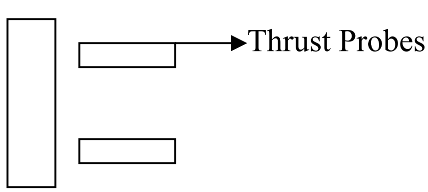
Non latching alarms will automatically resets hen the measured value decreases below its alarm set point.

First out
This option detects the first channel in the rack with first out installed, to signal an alert or danger alarm condition. Flashing alert LED indicates the first channel to go into alarm condition . if another channel goes to alarm condition before the first alarm is cleared the LED on that monitor will illuminate steadily.

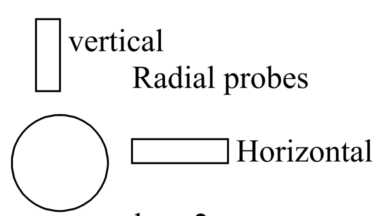
Danger relay voting logic
For dual channel monitors, AND danger voting logic allows either channel to generate an alert or danger alarm independently. However both channels measuring a danger alarm condition, are required to activate the danger relay.

In a dual channel thrust position with 2 probes can be configured as AND voting as this represents the same measurement variable (transducer redundancy). In this case a transducer fault will not cause a trip.

In the case of XY applications (2 orthogonal probes per bearing), the radial transducers can not be considered as redundant because they do not measure the same variable. One measures X direction vibration while the other one measures Y direction.



Two probes, one measurement variable
= AND voting logic



two probes, 2 measurement variable
= OR voting logic

Recorder outputs

4-20ma output is available for connecting to a recorder.

API 670
American petroleum institute has established standards for non contacting vibration and axial position monitoring systems. Recorder option, power up inhibit, OK circuit, timed OK/ channel defeat, danger bypass, alarm time delays, alarm voting, first out and normal thrust directions are all called for API670.

Full scale ranges

The choice of which range option to select for a particular monitor on the expected maximum value of the measured parameter. For radial vibration monitors, ranges should be based on operating experience. Also machine manufactures recommendations should be considered.

For position monitors the range is normally selected based on the available clearance of the thrust bearing (consider cold and hot operating clearances). Also rotor/stator clearances during startup, or the anticipated maximum excursions (or stroke) of the measured parameter can be used. In the 3500 system this can be easily changed in the field.

Transducer input option

The sensitivities such as 100mv/mil and 200mv/mil to be configured in the field for correct calibration.

Gap alarms

The 3500/16 monitor offers over and under gap alert alarms to alert machinery operators to change in shaft position. This may or may not increase the amplitude of vibration. The gap values and alarm set points can be volts or engineering units in the front panel. Gap alarm time delays are sec.

Trip multiply

When activated the function multiplies the selected monitors alarm set points by 2X or 3X (specified at time of order). Bently recommends the use of “trip” multiply only when normal vibration levels are expected to increase beyond the alarm set points for some (brief) period. An example may be during machine start up. Trip multiply consists of an alarm set point multiplier circuit in each monitor, external contact closure terminals at the rear to activate a switch and an LED on the front panel of the system monitor.

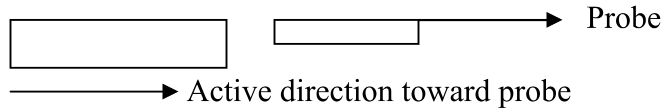
The multiplier is individual for each monitor. We can select which monitors in the rack are to operate with the Trip Multiply function. This is recommended to be operated by a spring loaded switch. That is the switch must be physically held for the trip multiply function to be activated.

Trip multiply is only available for radial vibration monitors. Axial thrust monitors which is measuring position is not expected to increase 2X, 3X like this. This is factory installed and not filed programmable.

Frequency response option
The frequency response option is to be selected based on the expected vibration frequencies of interest. The factory shipped configuration is 240 to 2,40,000 cpm.

The 1 to 600Hz (60 to 36000 cpm) option is not recommended for machine applications with rapid startup and coast down rates where acceleration/ deceleration exceeds 1000 rpm per second. Because of the expected low frequency range of 60 cpm, the monitor circuitry will retain vibration transients normally experienced during fast startups (such as with motor driven equipment). This can hold vibration levels above alarm set points beyond alarm time delays. This may result in danger alarm actuation even though the actual vibration has decreased below the danger alarm set point. The low frequency option is recommended where shaft rotative speed is below 1000rpm.

Normal thrust direction
The "toward probe" or "away from probe" option allows 3500/20 monitor to read correctly as the shaft moves toward or away from the probe. The monitor label "normal and counter" should correspond to "active and inactive" shaft directions of the machine.



Danger Bypass/ channel bypass
This function allows the danger relay to be disabled. The RED bypass led will be ON in this condition. The OK led will remain lit. a jumper on the circuit board can disable the Danger Bypass Switch. Normally the danger bypass switch disabled position is preferred.

The channel bypass allows a single channel in case of a single channel circuit fault. A channel's LCD, recorder o/p, and relay drives are bypassed during this function . Red bypass led will be on but Ok led will not be on.

Power Up inhibit
This minimizes false alarms due to transient power surge or loss and subsequent reapplication of power. This inhibits alarms for 2 seconds after power has been stabilized. Then Timed OK/ channel defeat becomes active again. This is as per API 670.

Timed OK- channel defeat
Timed OK- channel defeat minimizes the possibility of false alarms. This alarm may be caused by a defective transducer, its associated interconnect wiring, or transducer pwer supply.

When the OK limit is exceeded, the channel is defeated and the OK led is turned off. When a channel is defeated that channel is not providing machinery protection. The microprocessor then checks for proper transducer operation to be reestablished.

When the fault clears the channel is put back into operation (typically after 30 seconds delay). The green OK led will flashes at 1Hz rate until the user initiates a reset. If the problem persists the channel can be bypassed.

Key phasor Operation and application

This is a transducer installed in a machine train to generate a pulse per revolution. This provides reference for data taken on that machine. This is a reference mark and timer for speed, phase angle measurement and all data acquisition. This is invaluable when trying to diagnose and correct specific malfunctions of rotating machinery.

The pulse from the key phasor is normally input to instruments such as tachometers, vector filter phase meters, or any other instrument requiring a reference timing pulse for synchronous data sampling.

This is a proximity probe usually mounted to observe a key or keyway which provides a large gap change in front of the probe. As the proximity probe is a gap to voltage transducer when the key or keyway passes the probe a voltage pulse is produced. Since the key or key way passes the probe once each revolution, the voltage pulse occurs at a frequency equal to the speed of the machine.

Key phasor installation

The probe should be installed to observe key or keyway on the rotor. Care should be taken to ensure that the initial gap setting will allow for a voltage change of 5volts. The effects of thermal growth and normal shaft position changes must be taken into consideration when locating the key phasor probe.

The minimum target width (key or keyway) should be between 12mm and 16mm when using 8mm transducer. The depth should be sufficient to produce 5 volts. For a standard probe this should be 0.7mm deep.

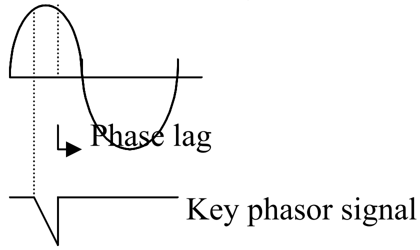
Under normal conditions a machine rotor will expand due to thermal effects as the machine heats up to operating temperature. If the key phasor probe is located at the end of the rotor away from the thrust bearing, ensure that the slot is sufficiently long enough so that it does not move from under the probe. This is particularly important if the key phasor slot is machined in the end of the rotor. Also care must be taken with axially mounted key phasor probes to avoid physical contact between the probe and the rotor and to make sure that the rotor does not move too far away from the probe so that pulse becomes less than 5volts.

Key Phasor Functions

Speed measurement :-

As thease probes produces a pulse for each revolution this probe can be used to measure speed. But at low speed multiple pulses produced by observing a gear or toothed wheel should be used rather than the key phasor.

Phase measurement :-



Absolute phase is measured from the key phasor pulse to the next positive peak in the vibration signal and is always expressed as a lagging angle between 0^o and 360^o. this may sometimes written as –ve angle.

The key phasor can be used t trigger the signal in the oscilloscope o produce a stable display.

Serial interfaces

The serial data interface (SDI) is a distinct communications interface between a host system and a 3500 rack. The SDI collects data and status values from the monitors within the rack.

By using third party software the values obtained from the rack can be viewed and stored. The SDI connects the rack to Allen Bradley computer or Honeywell monitor system.

SDI is a communications processor that gathers and stores values for static data values and monitor status from each monitor with in its rack. The SDI sends the stored values after receiving a request from the host computer system.

SDI communicates with each of the monitors within the rack using serial communications link. If the SDI is operating alone it will automatically configure itself on reset or power up. It will then step through the monitors collecting data and status from each monitor.

The SDI supports the allen bradeley DF1 and Modicon Modbus protocols. The interface can transmit over RS232 or RS422 physical link connections at baud rates up to 19.2k. racks can be daisy chained together when using modicon modbus. The rack to rack communications across the daisy chain is always RS 422. set the SDI jumpers to RS422 for all but the first rack in the daisy chain. Allen Bradley DF1 does not permit daisy chaining of racks.

The SDI collects a variety of information from each of the monitors in the rack. The SDI can send up to 16 static values for each monitor slot including fast trending on proportional data, GAP, channel status and alarm status. When using Modicon Modbus, the SDI can send the host computer the monitor set point values. The SDI can only obtain static data; to collect dynamic data from the rack requires the Dynamic Data Interface(DDI) and TDM2 software.

The communication channel of SDI is flexible. By using jumpers, we can set baud rate, device address, error checking, parity, stop bits, modem control and protocol.

SDI board

The SDI board or SDI is inside the 3500/03 system monitor. Some of the options include addressing, baud rates, communication options (Modbus, Allen Bradley) and modems.

Connection to Honeywell PLC gateway or Data highway Port

The Honeywell PLC gateway (PLCG) provides an interface between RS 232C devices using Modicon Modbus Protocol and the TDC 3000 Local Control Network (LCN). The data highway port (DHP II) provides a similar interface to the Honeywell Data Htghway.

The SDI implements the Modicon Modbus protocol and communicates Via RS232C on a link to a Honeywell PLC gateway (PLCG). The PLCG provide an interface between the serial data interface and the TDC3000 LCN.
The PLCG provides an interface between RS232 devices using Modicon Modbus protocol and the TDC 3000 LCN, the DHPII provides a similar interface to the Honeywell Data Highway.

Connection to Allen Bradley Data Highway or Data Highway Plus

The serial data interface is designed to work on an Allen Bradley Data Highway or Data Highway Plus network via a 1770KF2, 1771KE or 1785KE communication interface.

A communication interface module is the interface between the SDI and the Allen Bradley data highway.

The protocol implemented in SDI is Full Duplex DF1 protocol

Data Available – Modicon Modbus and Allen Bradley

Direct Values :-

The direct values address range is compatible with the 3500/01- 02 serial interface system monitor. Direct values have a starting address of 0 and occupy continuous protocol address. The first monitor(slot 1) is the left most monitor just to the right of the system monitor. The entire rack’s direct values are located sequentially in adjacent addresses. Each monitor will have 2 direct values associated with it, except 6 cannel temperature monitors (3500/30 or 3500/35) that have 6 direct values.

Current proportional values

Depending upon monitor type the proportional values include monitor values such as direct (ex. Overall vibration amplitude) probe gap, 1X and 2X amplitude and phase.

Proportional values

The SDI displays proportional values based on METER SCALE for direct values and on 24V DC for gap values.

Direct values

Ex. 3500/16 monitor has a full scale of 10mils. If it is indicating 6 mils the proportional value is 60%.
But Gap Full scale is always based on –24v dc. Even if your gap full scale indicates another value.
Ex:- gap reading is –10v dc and full scale indicated on the gap window is 19v dc. But gap proportional value is –10 / -24 = 42%.

Thrust monitor values :- here zero is the center of the meter scale. Suppose the thrust reading at the right is 15mils from the bottom reading of 40mils. The total range is 80mils. Hence the proportional value is 15/80 = 18.5%.

Fast trend time stamp
The time and date stamp for the most recent fast trend sample.

Fast trend interval
The intervals at which the fast trend samples are taken. This is fixed at 15 seconds.

Number of fast trend samples
The number of samples which have been taken. Normally the samples are taken every 15 seconds for a period of 40samles. This leaves a history of the past 10minutes of data. The number of fast trend samples will normally be 40. however if the data is sampled immediately after the SDI has been powered up, or reset there may be fewer than 40 samples taken.

Fast trend samples
The current proportional values are stored every 15 seconds for a period of 10 minutes (40 samples). This provides a history of the past 10 minutes of machine information at 15second interval. Once the 40sampls have been taken the oldest sample is over written. This provides a continuous 10 minutes history of machine information.

Monitor status
The status of the OK, Alert and danger conditions on the monitor. This status is determined at the monitor level. If any channel is in alert, danger or not OK, then the monitor status will reflect the state of the channel. Individual channel alarms are not available.

Monitor mode statuses
Provides the status of the monitors. Such as

- Error code is stored in the monitor
- An error condition currently exists in the monitor
- The monitor is currently in set point adjust mode
- The monitor is currently under calibration/ program mode
- The monitor is currently under trip multiply mode
- The monitor has danger bypass switch active

Channel alarm statuses
Provides for individual channel alarm status such as Alert, Danger and Not OK status.

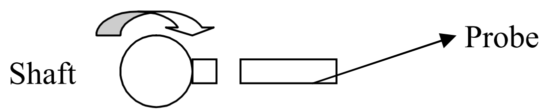
In the Bently Neveda (BN) vibration system, the main components are

- Probe Proximitor Extension Cable & Monitor.

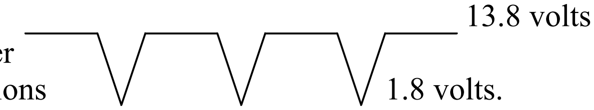
This is working according to the **Eddy Current** Principle. Eddy current is the electric current which circulates with in a mass of conductor when placed in a varying magnetic field.

The conducting material may be considered as consisting of a large number of closed conducting paths which behaves like short circuited winding of a transformer of which the varying magnetic field is the working flux. Eddy EMF if induced in this elemental path giving rise to the eddy current.

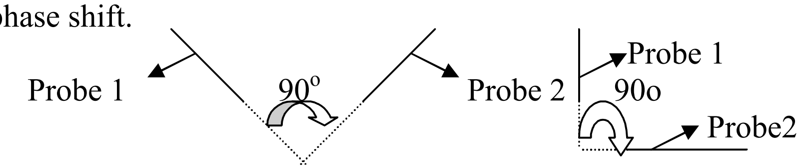
The probe is supplied with a high frequency RF signal from the proximitor. This radiates from the Probe tip. This sets up an electric signal which induces eddy currents into any conductive surface with which the field comes into contact. The output voltage produced by the proximitor is directly proportional to the gap distance measured between the probe face and the observed face.



Assume a shaft with a projection. The gap distance is adjusted to say 13.8 volts. As the projection passes the probe assume the voltage drops to 1.8 volts. Hence according to the number of times the projection passes the probe so much time the voltage will drop to 1.8 volts or the number of pulses. Thus the number of pulses per Minute is the number of rotations Per minute (RPM).



Similarly in a radial vibration system, there will be two probes mounted in such a way that they are at 90° phase shift.

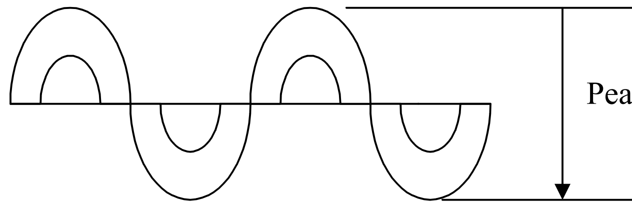


There are 2 methods of mounting as shown in the above figure.

One probe will sense the vibration in the horizontal direction and the other in the vertical direction. Most commonly used is the method 1 mounting.

When ever there is a vibration either in the horizontal or vertical direction the proximitor will produce an electrical signal proportional to the vibration level. The monitor connected to this will convert this peak to peak signal to vibration level on a linearly scaled panel meter.

During the installation of the probe, the probe will be fixed at a particular DC voltage known as Gap Voltage. In the case of radial vibration the produced signal is AC sinusoidal in nature and will be superimposed on this DC. The value of this peak to peak signal is the vibration.



In the case of radial vibration if the vibration level measured by any one of the probe goes beyond the danger level the system (ex. Compressor) will trip. In the case of 4K compressor used in gas plant trains, in the turbine side the alert (pre alarm) is 60 micro meters and danger (trip limit) is 85 micro meters. But in the case of compressor side the alert is 40 micro meters and danger 60 micrometers.

Example :- Assume we are using 200 mv/ mil sensitivity probe, the gap voltage is 10 volts and there is a vibration of 50 micrometers then the peak to peak value will be,

Sensitivity = 200 mv/mil

1mm= 40 mils = 40 * 200 mv = 8 volts.

1 micro meter = 8 mille volts.

50 micrometer = 50 * 8 mille volts = 400 mille volts peak to peak.

If we are using the multi meter for this measurement, the multi meter will show RMS value and the RMS= peak to peak/ $2\sqrt{2}$.

RMS value for 50 micro meter= 400/ $2\sqrt{2}$

In the case of Axial displacement (the displacement of the shaft either towards the probe or away from the probe) the gap voltage (DC voltage) will change corresponding to the movement and will be displayed in the monitor as axial displacement. If the shaft moves towards the probe the gap voltage will decrease (in amplitude wise- normally the gap voltage will be –7.5 volts to –10 volts, in this case it may go to say –7 volts or –9.5 volts) and if the probe moves away from the probe the gap voltage will increase (say to –8 volts or –10.5 volts). If the probe moves towards the probe it is normal direction and if it moves away from the probe it is counter direction.

In the Bently Neveda system the sensitivity of the probe will be 100 mv/ mil or 200 mv/mil. (1 mil= 1/1000 of an inch). In a 7200 system probe it is 100 mv/mil and in 3500 system it is 200 mv/ mil.

Assume we are using 200 mv/ mil probe and the shaft moved by 0.5mm. Let the initial gap voltage ie. 0 movement, be 10volts. Then the new gap voltage will be approximately 0.5mm = 20 mils= 20 * 200 mv = 4 volts. Hence the gap voltage will be 10 + 4 = 14 volts if the shaft moves away from the probe and 10-4= 6 volts if the shaft moves towards the probe.

In the gas plant for axial vibration, mechanical will complete the Bump test to find out the total free float of the shaft and let it be 16 mils. The alert is fixed as 10 + (16/2) = 18 mils and Danger as 15 + (16/2) = 23 mils.

BENTLY NEVEDA 3500 SYSTEM

3500 system has been enhanced to upgrade the computer/ communication interface options. The computer/ interface options are called the serial data interface or dynamic data interface (SDI/ DDI).

System monitor 3500/03

System power up inhibit:-

This allows each monitor to inhibit its alarms during power up or when ever a system power supply falls below its operating level.

Trip multiply

This function is to prevent unwanted monitor alarms during certain conditions of machine operation. In some machines for ex. During start up and coast down especially if the operating speed is above, rotor system balance resonances (critical speed), structural resonances and change in machine load or other operating conditions.

The trip multiple function causes the monitor alarm set points (both alert and danger) to increase by a fixed amount, either 2 times or 3 times according to ordering instruction.

How to calibration check of vibration Probe, extension cable and vibration monitor:

- Physical check of vibration probe & extension cable for any damages, if it is please replaced with similar one.
- Check resistance of vibration probe and continuity of extension cable with standard DMM.
- Use below equation and get reading for calibration of vibration probe.

1 mils = 0.001 inches
1 mils = 0.0254 mm
1 mils = 25.4 micron
1 mils = 200 mvdc

$$\text{RMS VALUE} = \frac{\text{Mils} \times \text{Scale Factor}}{2\sqrt{2}} = \text{(VAC)}$$

$$\text{VDC} = \text{Mils} \times \text{Scale Factor}$$

- Connect test equipment.
- Adjust te spindle micrometer on the TK-3 test and calibration kit shown 0.51 mm (20 mils) (0.0254mm=1mm).
- Insert the probe in to the TK-3 probe holder adjust the probe in the holder until the digital multi meter shows -3.00 ±0.10 VDC.

- Adjust the micrometer to 0.20mm (8 mils) indication and the back it out again to the 0.25mm (10 mils) indication backless in the micrometer forced the o/p voltage.
- Increase the gap in 0.25 (10mils) increment by adjusting the micrometer record the voltage indication at each increment.
- For each gap increment subtract the voltage at the high gap from the voltage at the low gap divide the result by in a system incremental scale factor of 7.87 ±0.79 v/mm (200 mv ±20 mv/mils).
- Subtract the 0.25 mm (10 mils) voltage (-5 vdc) from the 2.28 mm (90 mils) (11 vdc) and divided by 2.03mm (80 mils). The result should ina system average scale factor (ASF) of 7.87 ±0.43 v/mm (200 mv ±11 mv/mils).
-
- If the incremental scale factor or the average scale factor of the system is out of tolerance (refer to the specifications in appendix C).

Best wishes-

D.Chakraborty- **Power Plant Instrumentation & Control Engineer**