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## Throwback Thursday :: Bently Nevada Dual Probe Versus Shaft Rider

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Bently Nevada has a rich history of machinery condition monitoring experience and has always placed a high priority on educating and helping customers manage & maintain their equipment better. Every week, an article or Application Note that was published by Bently Nevada 'back in the day' will be highlighted. Although the format may be dated, the information is just as valid and informative as the original printing.

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### Introduction

For several types of rotating machinery, the evaluation of overall mechanical integrity requires a measurement of rotor absolute dynamic motion (vibration), that is, shaft motion relative to free space or to a fixed point in space. Primarily, these machines have fluid film bearings and one or both of two characteristics: (1) Compliant bearing supports (low mechanical stiffness) that cause rotor vibration to be transmitted, to some degree, to the bearing housing and (2) a relatively low ratio of casing mass to rotor mass. Turbogenerator trains are a typical example of these machines [1]. Two types of transducers are available for measuring shaft absolute motion, the shaft rider and the Bently Nevada Dual Probe. This Applications Note compares the two methods of measurement from the perspectives of transducer design, operation and reliability. Moreover, consideration is given to the level of information provided, i.e., the degree of usefulness of the information available from each type of transducer.

### Shaft Rider

The shaft rider consists of a rod assembly which extends through the bearing housing and literally rides on the shaft via a spring-loaded mechanism (Figure I). The top of the rod, outside the machine casing, is directly attached to a seismic transducer, usually a velocity pickup but

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sometimes an accelerometer (Figure 2) Through its spring-loaded mechanism, the rod attempts to follow the motion of the shaft. The attached seismic transducer produces a signal representing shaft absolute motion at frequencies above the threshold of the transducer.

The shaft rider has been in use for several decades. It was originally introduced as an enhancement to seismic bearing housing measurement transducers for making shaft measurements on large fluid film bearing equipped steam turbine generator sets. As with most mechanical designs of sliding and contacting parts, the shaft rider assembly is subject to wear. The shaft end of the rod must have constant lubrication of the proper amount. Too little lubrication will cause a dry rub and resulting chatter; too much lubrication will cause insufficient direct contact with the shaft and even hydroplaning. If the rider is near a high pressure region of the machine, a selleak can cause the rod to be pushed up like a piston. Under extreme cases, improper shaft rider contact may even damage the shaft surface.

The lower end frequency response of the system is limited by the characteristics of the seismic transducer. While some electronic signal conditioning can offset the amplitude and phase errors at low frequencies, the practical lower limit is usually around 10Hz (600 cpm, usually 900 rpm on many units). The upper frequency limit is primarily a function of the ability (or inability) of the spring loaded mechanism to allow the rod to faithfully follow the shaft motion. It is not practical for the upper limit to be higher than 100 Hz (6000 cpm). Given these frequency limits, the shaft rider cannot measure, and in fact completely ignores, the amount of shaft bow (thermal and/or mechanical) at machine slow roll (turning gear) speeds. It also cannot accurately measure vibration frequencies higher than two times shaft rotative speed for the most common operating speed applications (3000 or 3600 rpm).

In addition to the frequency response discussion above, the velocity transducer itself has other characteristics which deserve consideration. Since it is an inertially referenced mechanical system (spring/mass/damper), its performance may degrade over a period of time, even under normal use. Annual calibration checks of each velocity transducer are generally recommended. Calibration itself requires a significant amount of effort; the procedure cannot easily be performed in the field as it requires an accurate dynamic reference shaker table.

## **Bently Nevada Dual Probe**

As the name suggest, the Dual Probe is a combination of two transducers [2]. The Dual Probe assembly consists of an eddy current displacement proximity probe and a velocity Seismoprobe® (Figure 3). The proximity probe was introduced in the mid-1960s as a replacement for bearing housing transducers. Used alone, it is the only type of transducer necessary for making measurements on machine types which exhibit small bearing housing motion as result of shaft motion. For machines with significant amplitudes of both shaft and housing vibration, the proximity probe is installed in conjunction with a Seismoprobe on the bearing housing. Both transducers measure in the same axis and have the same measurement reference, the bearing housing. This

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combination is known as the Dual Probe.

The proximity probe measures shaft motion displacement relative to its mounted location, e.g., the bearing housing. The velocity Seismoprobe measures bearing housing absolute velocity motion. In order to obtain the measurement of shaft absolute motion, the velocity signal is integrated to displacement, amplitude and phase corrected for lower frequencies, and then a summing amplifier vectorially adds the two transducer signals.

A Dual Probe assembly is no more immune from limitations associated with the velocity Seismoprobe than a shaft rider. However, for applications where shaft relative motion is higher than bearing housing absolute motion, the primary vibration is measured by a proximity probe, a superior transducer from many standpoints- design (solidstate), accuracy, long-term reliability, frequency response and ease of calibration, to name a few.

Since the proximity probe has no moving parts, there is no associated wear as with a mechanical or electromechanical system design. Except for infrequent electronic component failures, the proximity probe lasts indefinitely and has successfully passed 40-year accelerated life testing required for nuclear power plant applications. Resolution is easily 0.0001 inch and can be greater with careful calibration. Calibration itself is simple and straightforward; static calibration (micrometer) verifies both steady-state and dynamic operation. For spare parts purposes, the same type of probe used for vibration measurement can also be used for axial thrust position and rotor speed measurements as well as a phase reference (Keyphasor®).

Frequency response of the proximity probe is typically from 0 Hz (dc) to 10 Hz. Thus, it is capable of measuring shaft motion at frequencies many times rotative speed frequency. Because of the lower end response to dc, it simultaneously measures both dynamic motion (vibration) and average shaft position. In addition, it easily measures shaft motion (rotor bow) at slow roll and turning gear speeds. Knowledge of the slow roll bow vector is essential for effective trim balancing [3].

The only significant disadvantage of the proximity probe is its dependence on a homogenous shaft material with smooth surface finish free from small spot magnetic fields. While nonhomogeneity and spot magnetism cause electrical runout (false reading at slow roll and, therefore, at all higher speeds), these problems can be corrected through proper care of the shaft area and, if necessary, some shaft treatment methods. Several technical papers and other Bently Nevada Application Notes have been written on the elimination of electrical runout sources [4].

Although the quality of shaft surface finish is important when using proximity probes, it is likewise significant when using shaft riders. Erroneous readings will result with either type of transducer if the shaft is nonconcentric, has scratches, flat spots, chain marks, or other surface irregularities. Figure 4 shows the output signal characteristics of a shaft rider with a slight flat spot on the shaft in the path of the rider. Actual vibration at this measurement location was less than one mil. This was later confirmed with a proximity probe using electronic runout compensation. Runout compensation

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is performed electronically by vectorially subtracting the slow roll (runout) signal from the overall signal at any higher rotor speed. Since the shaft rider has no meaningful output at slow roll speeds, this technique can be used only with proximity probes and Dual Probes.

## What do the measurements mean?

The most important factor in comparing the Dual Probe and shaft rider is the machinery information available from each. Considering the two measurement techniques, what information is provided about the running condition, mechanical performance and ultimate mechanical integrity of the machine?

The shaft rider provides one piece of information:

- Shaft absolute dynamic motion.

Certainly for machines with significant vibration amplitudes of both shaft relative motion and bearing housing absolute motion, usually the ultimate concern is total or absolute motion of the shaft. However, this is the only bit of information available from the shaft rider. Also, one vertical shaft rider per radial bearing is typical, so that no information of the horizontal shaft motion is available.

The Dual Probe provides four pieces of information:

- Shaft absolute dynamic motion.
- Shaft dynamic motion relative to the bearing housing, including slow roll data.
- Bearing housing absolute motion.
- Shaft average radial position within the bearing clearance (or relative to the bearing center).

Transducer assemblies for both vertical and horizontal mounting are readily available, providing knowledge of the total shaft (orbit) motion. (Actually, transducers are available for any orthogonal angular orientation.) Allowing for the fact that shaft absolute motion may, in most cases, be the most important ultimate parameter, it is also important to evaluate the components of that absolute shaft motion, i.e., shaft relative and bearing housing absolute motion. If both shaft and housing are undergoing vibration of measurable amplitude, it is important to know if the housing motion is the result of shaft transmitted forces, housing resonance excitation, or vibration from some other external source.

Further, the comparison of shaft relative and housing absolute motion permits the evaluation of system mechanical impedance. It is necessary to measure the amplitude and phase relationships of the two motion components in order to determine the effects of bearing damping, support stiffness, inertial properties, and other characteristics of the mechanical system.

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The measurement of average shaft radial position relative to the bearing clearance or bearing centerline is very meaningful in evaluating the running condition of the machine. Average shaft position, defined by machine and bearing designers as an "eccentricity ration" is an indicator of the steady state, unidirectional preload forces acting on the rotor. All journal bearing systems have a designed "normal" average position for the shaft. Any deviation from that position indicated the presence of preloads, many of which are undesirable. A sufficiently strong preload acting in the approximate opposite direction of normal bearing load will make the system more susceptible to forward instability mechanisms, such as oil whirl and whip. In addition to evaluating bearing load, average shaft position information is a direct indicator of the internal and external alignment condition of the machinery [5], and can indicate excessive bearing clearance (bearing wear).

Many machines which require shaft absolute measurement are subject to initial rotor bow, e.g., mechanical thermal, gravity, etc. These include steam and gas turbines as well as some large fans, pumps and other machine types. Initial shaft bow measurement is only available from a transducer which responds at slow roll frequencies, i.e., the Dual Probe. While machines equipped with shaft riders usually have a separate transducer (noncontacting, inductive type) for slow roll bow measurement, this is provided at only one location along the shaft. It is important to know the extent of shaft bow (amplitude and phase) at any available locations, particularly at the vibration measurement locations. This information is necessary to accurately evaluate shaft vibration at running and other rotor speeds. The slow roll shaft bow signal can be electronically or graphically compensated, yielding the actual shaft dynamic motion amplitude and phase. This procedure is mandatory for the purpose of accurate and effective rotor balancing [ 6).

## Conclusion

Simply stated, the shaft rider was a satisfactory vibration transducer for its day, but it has been superseded by current technology. Over more than a decade of industrial service, the Dual Probe has proven to be superior. In addition to improved accuracy, reliability, maintainability, etc., the most important advantage is the quality and quantity of information about the mechanical condition of the machinery.

Since the late 1960s, some machine manufacturers have been providing the Dual Probe instead of previously-used shaft riders. Other manufacturers have more recently made the change, supplying Dual Probes on new machinery as well as replacing shaft riders with Dual Probes in system upgrade retrofit situations. Today, most of the major worldwide suppliers of large steam turbines and a number of manufacturers of industrial design gas turbines have changed or are changing from the shaft rider to the Dual Probe. Perhaps the best support of this technology is a publication from a turbine manufacturer. This manufacturer recently circulated a flyer offering customers an upgrade program including replacement TSI systems. The following excerpts concern shaft relative versus shaft riders.

On the use of shaft absolute rather than relative vibration measurement:

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"This is dependent upon the construction of the bearing housing on that particular unit. On many older units, the bearing housing are a heavy cast material having little or no movement at the critical vibration frequencies. A reading of vibration relative to that bearing is then adequate. Absolute vibration measurement is recommended on units which have fabricated bearing housings. This absolute system includes a relative sensor to measure shaft movement in relation to bearing movement, and a seismic sensor to measure bearing movement in relation to a fixed frame of reference."

On the comparison of Dual Probes and shaft riders:

"Proximity sensors do not contact the shaft surface at all, but obtain a reading about 0.050 inch from the surface by transmitting and receiving a magnetic field and getting its measurements from the field intensity which is proportional to gap distance. There are no moving parts (except the seismic sensor for absolute measurement), providing excellent reliability and no wear. Accuracy and sensitivity are good up to 10KHz frequency. Shaft riders directly contact the shaft causing wear between shaft rider tip and the shaft. It must be located in a lubricated area, which usually means going through a bearing. The shaft rider is susceptible to "oil whip" and has poor frequency response (good from 10- 120Hz). Due to moving parts and direct contact, sticking, slip bounce, squeal, and chatter can occur, providing erroneous readings. Some of these factors also make it difficult to calibrate a shaft rider system."

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1631 Bently Parkway South, Minden, Nevada USA 89423

Phone: 1.775.782.3611 [Bently.com](http://Bently.com)

