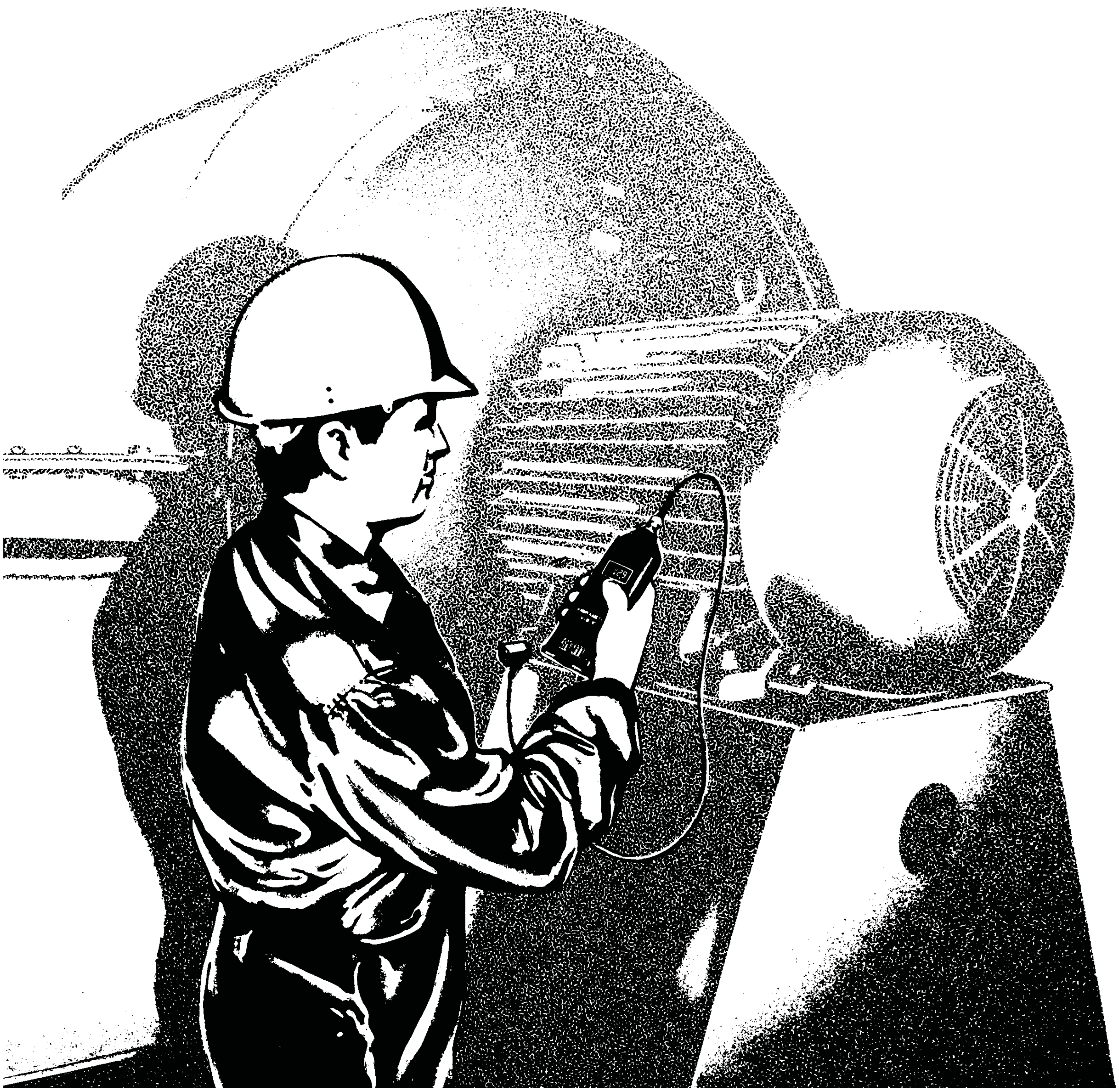
Instruction Manual

# Vibrameter VIB-10 B



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# Condition Based Maintenance

Condition Based Maintenance is by now a widely accepted concept in industry. The idea is simple and not exactly new: keep plant machinery in good working condition by locating and repairing minor faults before they grow large enough to cause expensive breakdowns and production stops.

The problem is to assess machine condition and detect a slow deterioration long before a piece of plant grinds to a shuddering halt. In the past, a skilled operator could do this largely without the help of instruments, by listening, touching, smelling. Modern machinery is often unattended, soundproofed, out of easy reach. It rotates faster and is less massively constructed, which means that even a minor deterioration of its working condition can have very serious consequences. Therefore personal skill and subjective judgement have to be supported by monitoring systems and instrument readings.

# Vibration Monitoring

Vibration monitoring is a very useful method for an overall assessment of machine condition. Changes in the vibration level always imply changes in the operating condition. Excessive vibration has basically three causes: something is loose, misaligned or out of balance. These three causes cover virtually all possible mechanical faults.

Moreover, the assessment of machine vibration has been much simplified by international standards which define the acceptable vibration level for a given type of machine and recommend monitoring methods suitable for industrial purposes.

# A Maintenance Tool

Effective Condition Based Maintenance requires economical and simple monitoring methods which can be applied by maintenance personnel without special training. Their primary task is to locate trouble spots early and direct the efforts of the maintenance crews to the right place at the right time. Fault analysis and repairs are a secondary step which may require expert knowledge and a different type of instrumentation.

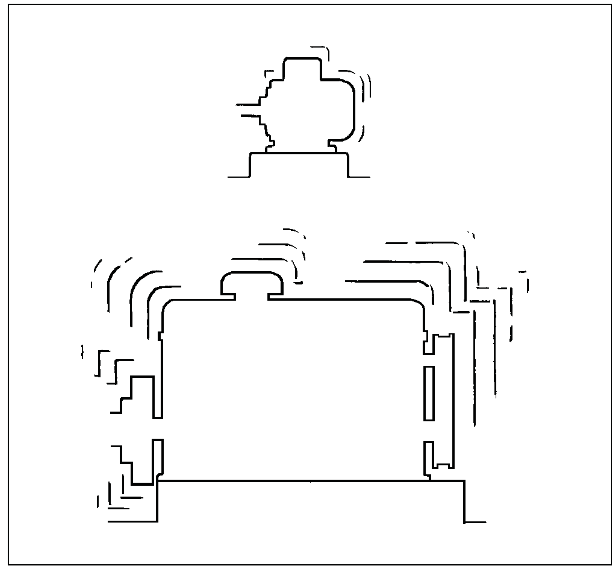
SPM vibration monitoring equipment is designed as a maintenance aid. In accordance with the international standards, it measures vibration severity over a large frequency range. It allows a practical classification of machine condition in relative terms: good, acceptable, just tolerable or bad. Regular measurements will also show the development trend of the vibration level and thus the urgency of the maintenance problem: stable condition, slow deterioration or fast deterioration.

Measurements can be carried out in various ways; either periodical readings with portable equipment (Vibrameter VIB-10), or continuous monitoring of preset limit values (SPM MG4 or CMM System). This manual gives an introduction to vibration monitoring and describes condition assessment and basic fault analysis with SPM Vibrameter VIB-10B.

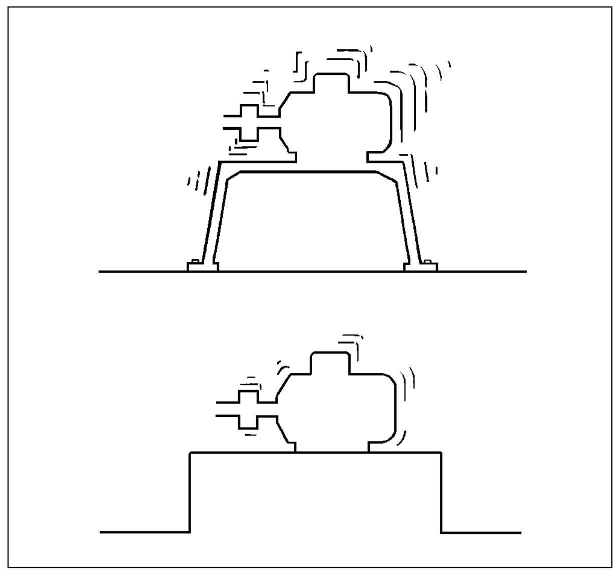
# Vibration

In every moving machine, part of the force that makes it work acts on the machine itself. Since no structure or machine is perfectly rigid, any force acting on it will cause slight movements.

The forces causing movement are usually cyclic, that is they operate regularly first in one direction and then in another. They can act in two main directions, like the up and down forces associated with piston engines, or they can rotate with the shaft, like out of balance forces on a fan. They move the machine back and forth from its rest position: the machine vibrates.



Up to a degree, vibration is tolerated because it simply cannot be avoided. Machines are designed to withstand a "normal" amount of vibration for a long period of time. To assess the condition of any particular piece of plant, one has to determine its "normal" vibration level, then measure the actual amount and type of vibration and compare the two values.

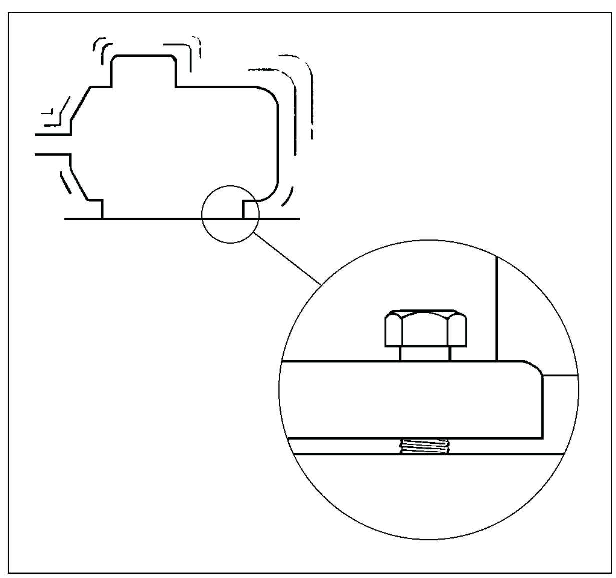


To decide what is normal one has to consider

- **the function of the machine and the forces involved**
- **the rigidity of the machine structure**

A large diesel engine vibrates more than a small electric motor - the forces involved are very different.

More force is needed to vibrate a machine on a stiff concrete foundation than it takes to shake the same machine on a flexible metal frame. The machine structures are different and so are their normal vibration levels.



Due to changes in the operating conditions and the mechanical state of machines, vibration levels are subject to gradual or sudden changes. Loose fixing bolts or excessive bearing play will make the structure less rigid - vibration will increase. A growing soot layer on the impeller blades of an exhaust fan adds to the out of balance forces. Vibration will increase above the normal level and show that the machine is getting worse. Usually the deterioration accelerates: heavier vibration will further weaken the structure which in turn will raise the vibration level.

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# Measurement

If a fan is out of balance, it will shake at its speed of rotation, i.e. move backwards and forwards once per revolution. The number of vibrations per time unit is the **vibration frequency**, measured in Hz (Hertz = cycles per second).

The rotational speed of any piece of plant is known as its **fundamental frequency**. For a fan with a speed of 1 500 r.p.m. the fundamental frequency is 25 Hz (1 500 r.p.m. ÷ 60).

In practice, machine vibration usually consists of many different frequency components. For a general assessment of machine condition one uses **wide frequency band measurements**, that is all vibrations within a large frequency range are measured simultaneously.

Cyclic movement can be measured and described in three different ways, as

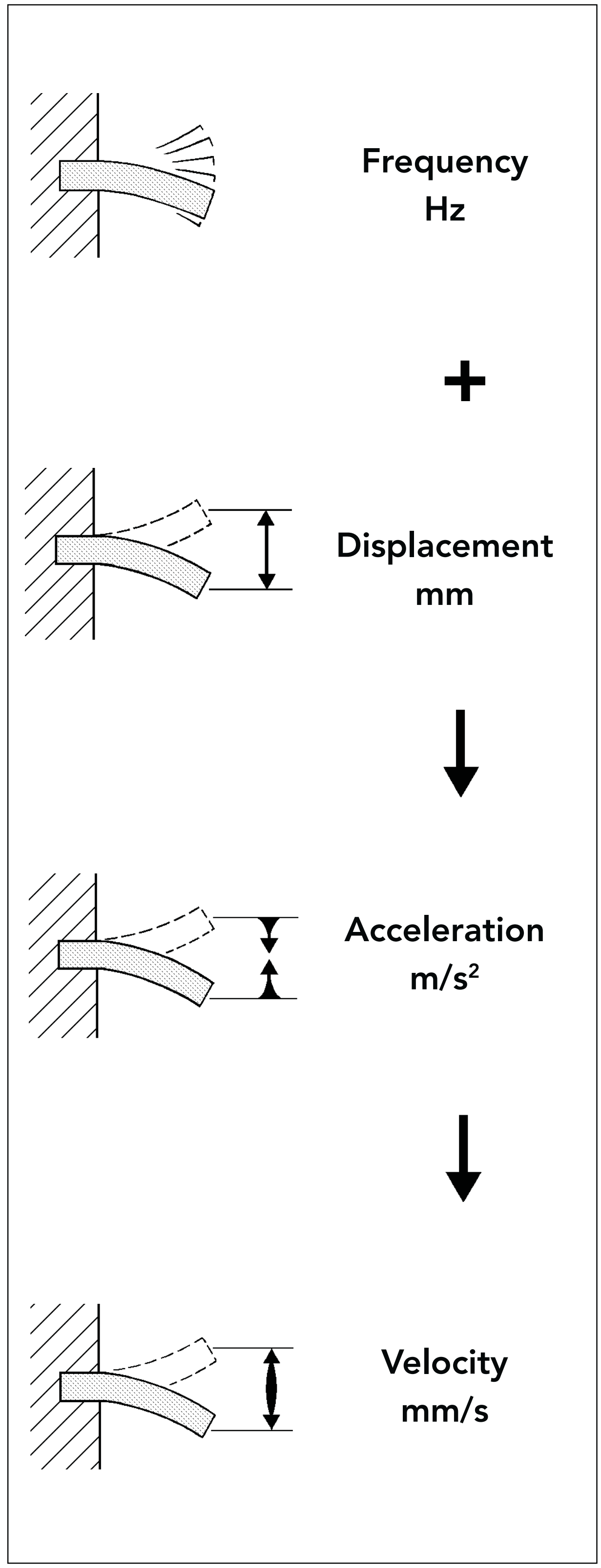
- **displacement**
- **acceleration**
- **velocity**

Displacement means the actual distance the object moves, measured either from its rest position in one direction (peak) or as the total movement in both directions (peak to peak). Displacement is measured directly in millimetres.

A part that is moving from rest, speeding up, slowing down and stopping twice per cycle is obviously accelerating and decelerating continuously. Acceleration is measured in m/sec$^2$ or g (1 g = 9.81 m/sec$^2$).

The third measuring parameter is the speed at which the object moves, the vibration velocity. Velocity is expressed in mm/sec.

Both acceleration and speed are constantly changing. One can measure a peak value of either, but a mean value often gives a better indication of the forces involved in the movement. Most instruments measure the **RMS value** (root mean square value) of the movement and use a scaling factor to indicate the peak levels if they are given at all.

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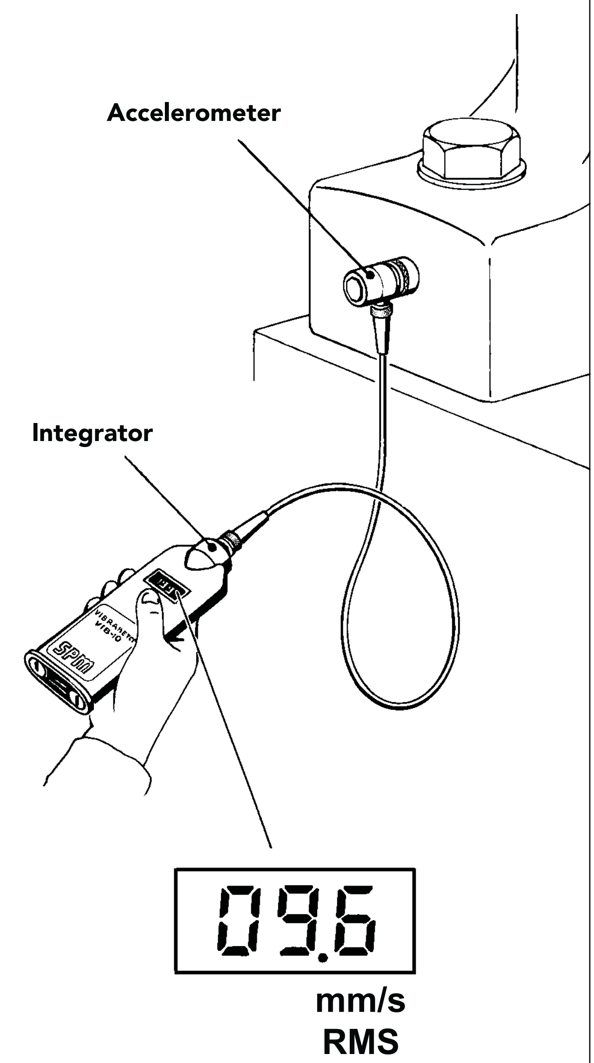
# Measure Acceleration - Display Velocity

All three vibration parameters - displacement, acceleration, velocity - are mathematically related. One can, for example, place an accelerometer on a vibrating surface and convert its signal, via integrating circuitry in the measuring instrument, into a reading of vibration velocity or displacement.

The choice of displayed parameter (the instrument reading) and measured parameter (the transducer type used) depends on the problem to be solved and on the cost, the complexity and the reliability of the measuring equipment.



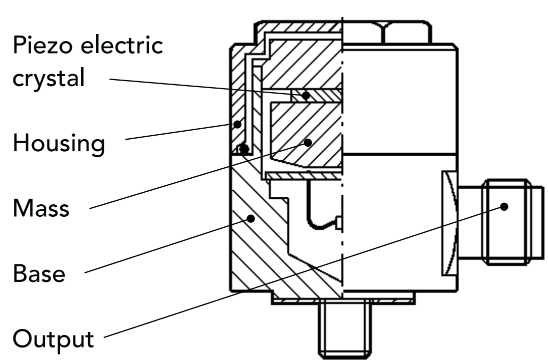

Experience has shown, that the RMS level of vibration velocity, measured over a frequency range of 10 to 1000 Hz, is most useful for general assessment of machine condition. The technical term used is **vibration severity**, defined as above and displayed in **mm/s RMS** on the instrument. Vibration severity is directly related to the energy level of machine vibration, and thus a good indicator of the destructive forces acting on the machine.

There are transducers which measure velocity directly, i.e. seismic probes with either moving coils or moving magnets. These transducers are normally bulky, easily damaged and expensive to manufacture. They are therefore gradually being replaced by accelerometers.

An accelerometer is basically a piezo electric crystal (a crystal that develops an electric charge when it is compressed or stretched) with a small reference mass attached. As the transducer is moved back and forth, the reference mass compresses and stretches the crystal and the transducer gives an output directly related to acceleration.

Piezo electric accelerometers are small, very robust and relatively cheap to produce. They can work over a very large frequency range. They can be mounted on machines, held by hand against a vibrating surface or be temporarily attached by wax or magnets. That is why most practical measuring systems now use an accelerometer as the transducer and an integrator within the instrument to give a display in terms of velocity.

**Piezo electric accelerometer**



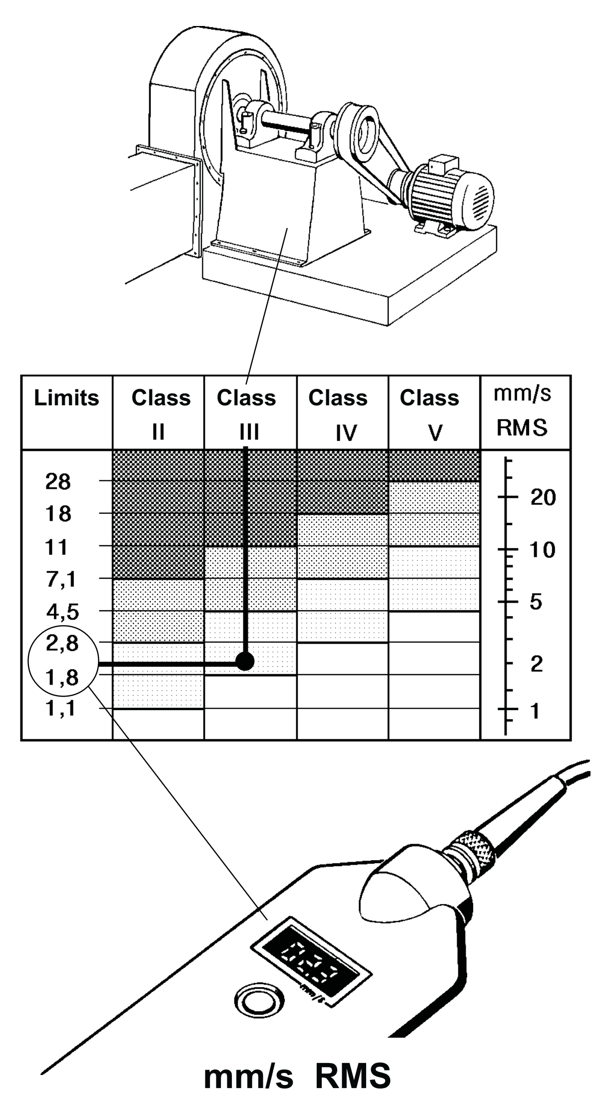
# Machine Classes

To assess machine condition, the vibration severity measured on a specific piece of plant has to be compared with a representative norm value.

The international standards group industrial machinery into six different vibration classes , depending on

- machine size and function
- stiffness of foundation

For each class, the standards give vibration severity levels in four bands, ranging from very good condition through average and poor to bad. Provided that the correct class is chosen, the instrument reading can be directly related to machine condition.




Most industrial plants belong to vibration classes II, III and IV.

Class I refers to independent parts of machines, for example electric motors up to 15 kW.

Classes V and VI are used for heavy reciprocating prime movers and machines which are intended to vibrate - for example vibrating screens (see Appendix page 15 for precise definitions).

Motor power and types (electric, turbine, diesel), machine size and foundation stiffness (concrete base, metal frame, etc.) will give a first indication of machine class. For example, most smaller process pumps on a chemical plant would be Class II. A 100 kW ventilation fan on a concrete base would be Class III. However, the same fan fastened to the less rigid metal deck of a ship could be considered as Class IV.

**II Medium size machines without special foundations**

**III Large machines on rigid foundations**

**IV Large machines on soft foundations**

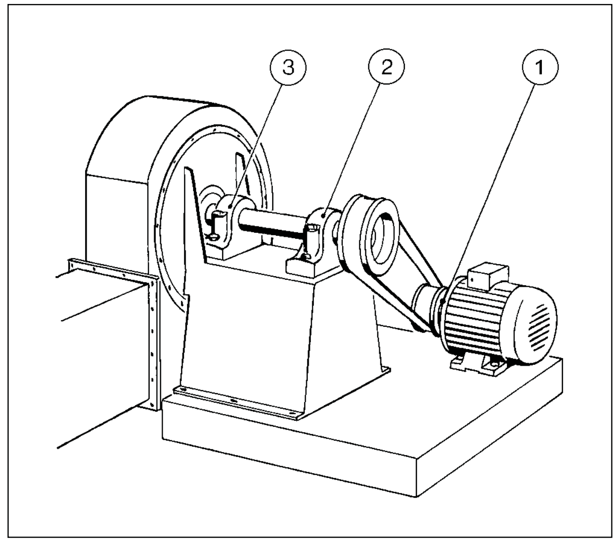
Classification of machinery is largely a matter of experience because the definitions provided by the standards are deliberately loose. Manufacturers should be able to specify acceptable vibration levels for their equipment, and their information can be used as a reference.

Similarly, if it is reasonably sure that a machine is in good condition, the actual vibration reading can be used as a starting point for the assessment of future changes.

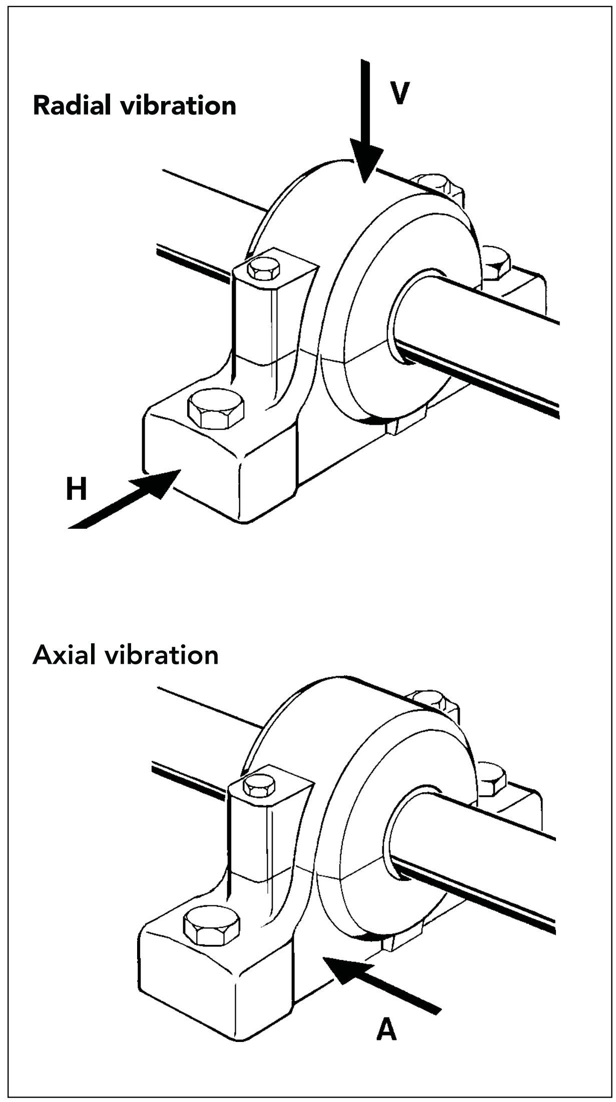
# Measuring Points

Vibration at the measuring point should be representative of the overall vibration pattern of the machine. The forces involved are usually transmitted through the bearings and their housings to the machine foundation. Consequently measuring points should be located on or near the bearing housings.

Machine guards, cover panels and other parts which are considerably less stiff than the main structure are not suitable as measuring points.




Generally speaking, the more measuring points chosen, the easier it is to locate a specific mechanical problem. Consider a fan, belt driven from an electric motor. Measurements taken on the fan bearing (3) will primarily give information on fan balance. If out of balance is the only problem to guard against, measuring on that bearing will be sufficient. To be able to make an adequate assessment of the mechanical state of the whole machine, one should also measure on the drive end bearing (2) and the motor (1).




The direction of measurement is very important. Out of balance forces rotate with the shaft and cause radial vibration acting in all directions within the plane of rotation.

Axial vibration, along the line of the shaft, is normally caused by faulty alignment, i.e. badly assembled couplings or bent shafts.

Normal practice is to take vibration readings in three directions at each measuring point: vertical (V), horizontal (H) and axial (A). Of the two radial measurements, a reading in the vertical direction tends to give information about structural weakness, whereas the horizontal reading is most representative of balance conditions.

The measuring point, meaning the exact spot on the machine where the transducer is placed, should be clearly marked and used each time a reading is taken. Relatively small changes in the measuring point can cause misleading changes in the measured value and trend analysis difficult.