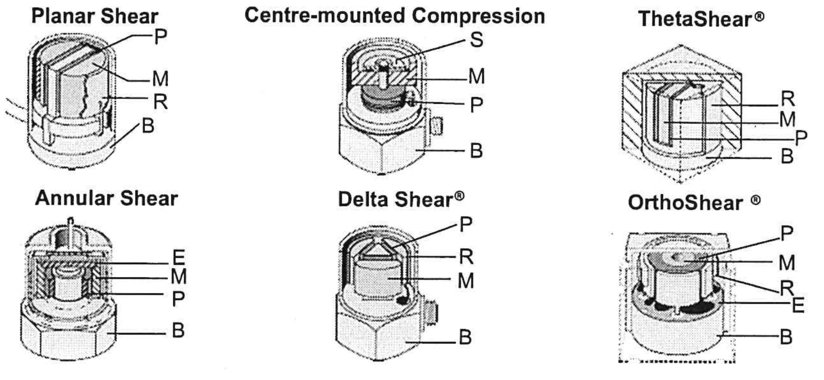
Types of Accelerometers



P: Piezoelectric Elements **E:** Built-in Electronics **S:** Spring

R: Clamping Ring **B:** Base **M:** Seismic Mass

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Compression Type Design

This traditional, simple construction gives a moderately high sensitivity-to-mass ratio. In the Centre-mounted configuration shown, the piezoelectric element-spring-mass system is mounted by means of a cylindrical centre post attached to the base of the accelerometer.

The design is very stable, but even with careful design the influence from environmental parameters is higher than for the other construction types.

Therefore this design is especially used for accelerometers which are intended for measurement of very high shock levels and special purpose accelerometers.

Shear Type Design

Shear type accelerometers have the advantage that they intrinsically are rather insensitive to environmental parameters like temperature transients and base strain. A high sensitivity-to-mass ratio can be obtained, and this helps to create miniature accelerometers as well as high performance general purpose accelerometers. The piezoelectric elements are arranged in such a way that they are subjected to shear forces from the seismic mass when accelerated.

DeltaShear® Design

Three piezoelectric elements and three masses are arranged in a triangular configuration around a centre post. They are held in place using a high-tensile strength clamping-ring.

The DeltaShear® accelerometers can be used for virtually any application. The advantage of the Delta Shear accelerometer is its excellent overall specifications and very low sensitivity to environmental influences.

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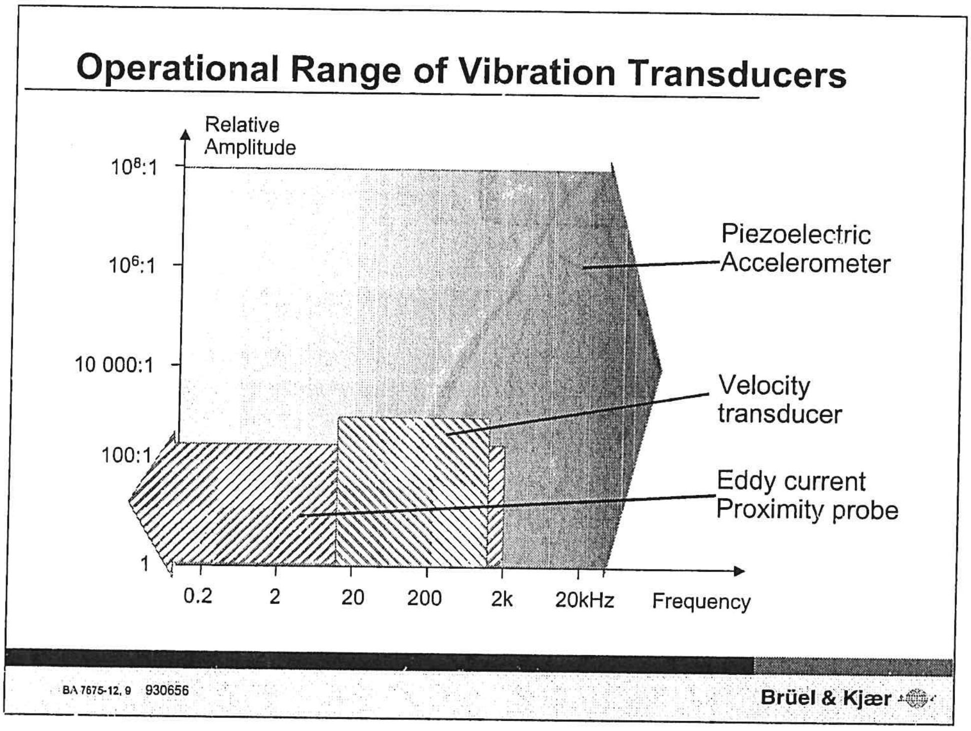

Ranges of Operation

The range of frequencies and levels within which the different transducers typically can operate differs significantly as stated earlier. A graphical representation underlines this.

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Planar Shear-Design

This design is a simplified DeltaShear® Design with only two piezoelectric elements and seismic masses. This gives excellent performance even when used in very small accelerometers.

Annular-Shear-Design

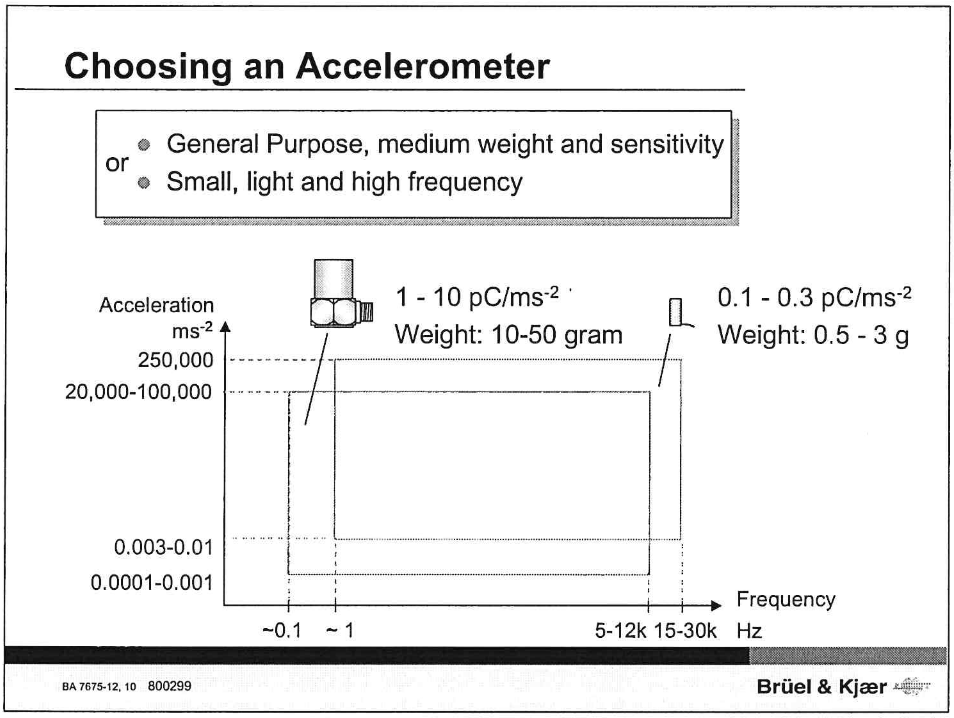
In this design the piezoelectric element and seismic mass are formed into rings and mounted around a centre post. The figure shows an accelerometer with built-in electronics and double shielding.

ThetaShear®-Design

This patented design combines the advantages of the shear design, electrical insulation from the mounting surface, simplicity, and low mass-loading to provide low-cost flexible well performing transducers.

OrthoShear®-Design (Triaxial)

This design (patent pending), developed for triaxial measurements, has a common seismic mass as reference point (centre of gravity) for all directions. This results in a compact design ensuring accurate and consistent measurements even when exposed to complex patterns of vibration. The seismic mass is surrounded by a piezoelectric ring and four terminals all held in position by a high tensile-strength clamping ring. The X, Y and Z outputs are obtained by appropriate connection to the terminals and summation of signals. Combines the advantages of the shear design, electrical insulation from the mounting surface, simplicity, and low mass-loading to provide low-cost flexible well performing transducers.



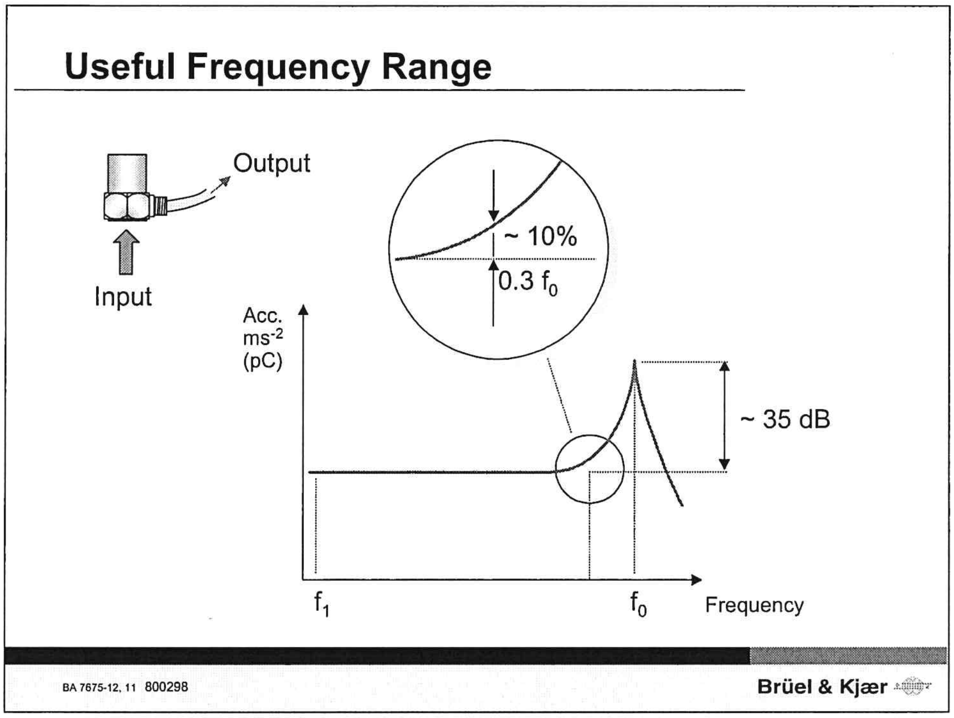
Selection of an Accelerometer

The range of operation is the first to be considered when selecting an accelerometer.

The graph shows two typical groups of accelerometers with typical specifications:

• General Purpose Type Accelerometers

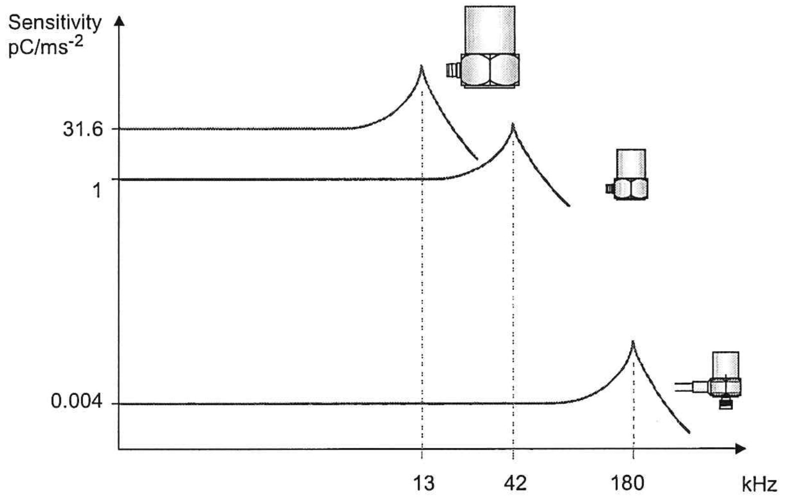
• Small (miniature) Accelerometers



Useful Frequency Range

All accelerometers will give a constant output signal for a constant acceleration from very low frequencies up to a limit set by the increase in output due to resonance of the accelerometer. In general, however, the accelerometer is not used close to its resonance as this could result in a big error in the measured signal. As a rule of thumb, the accelerometer can be used up to one third of its resonance frequency. This will then ensure that the error at that frequency does not exceed approximately 12% or 1 dB. 0.3 times the mounted resonance frequency gives 10 % as shown. Filters can be used to limit the response to well below the accelerometer resonance frequency, but the input stages will still have to handle any signals at the resonance. To avoid this, mechanical filters can be used. This will be discussed later.

Sensitivity and Frequency Range



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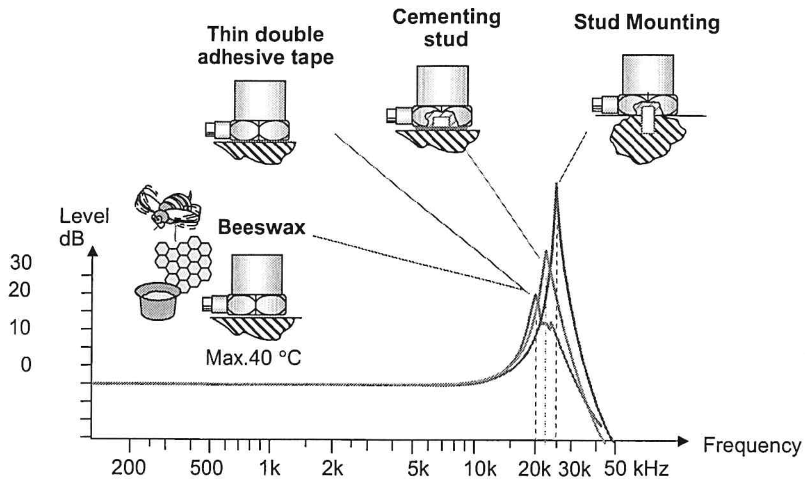
Sensitivity and Frequency Range

When the accelerometer is exposed to a constant level of acceleration it will give a constant output signal over a very wide frequency range up to frequencies near its resonance frequency. The sensitivity and frequency range of an accelerometer are related: in general the bigger the accelerometer the higher its sensitivity, and the smaller is its useful frequency range, and vice versa.

Accelerometer Mounting — Fixed



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The Importance of Correct Mounting

Bad mounting of the accelerometer can spoil vibration measurements by severely reducing the usable frequency range. The main requirement is for close mechanical contact between the accelerometer base and the surface to which it is to be attached.

Stud Mounting

Mounting the accelerometer with the aid of a steel stud is the best mounting method and should be used in all applications wherever possible. The unavoidable resonance of the accelerometer at high frequencies can cause erroneous signals and therefore the accelerometer output should be attenuated at these high frequencies.

Cementing Studs

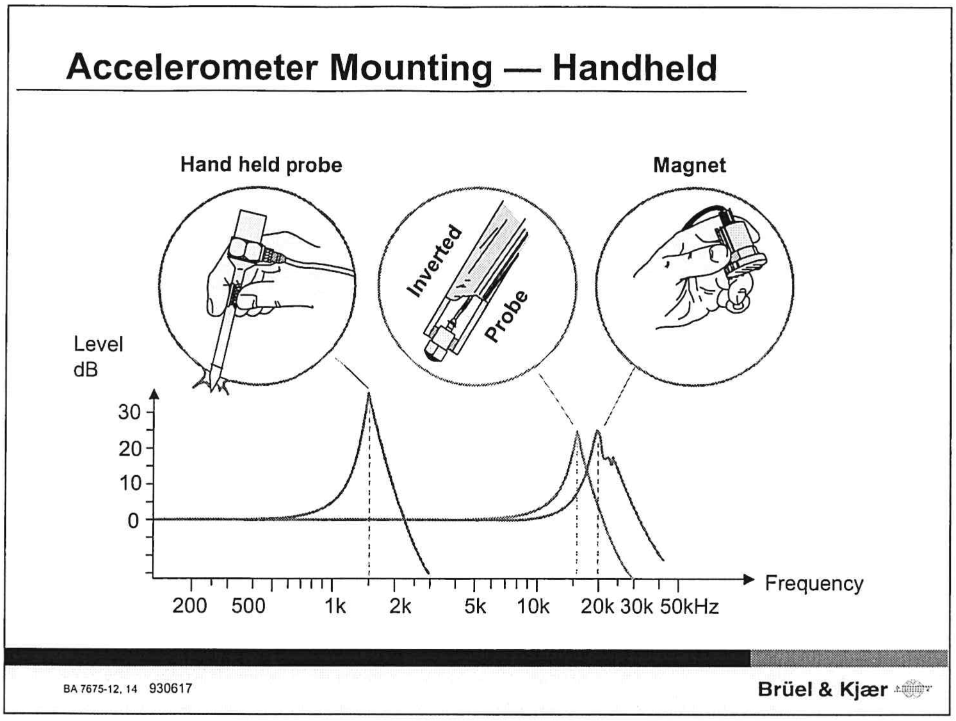
In places where it is not wished to drill and tap fixing holes, a cementing stud can be fixed onto the machine with the aid of an epoxy or cyanoacrylate cement. The frequency response will be nearly as good as that obtained using a plain stud. Soft glues must be avoided.

Mounting with the Aid of Beeswax

For quick mounting of the accelerometers e.g. for surveying vibration in various locations beeswax can be used for mounting the accelerometer. Because beeswax becomes soft at high temperatures, the method is restricted to about 40°C.

Isolated Mounting

In places where it is desirable to isolate the accelerometer from the test object an isolated stud and a mica washer should be used. This could be either because the potential of the test object is different from the ground potential of the test instrumentation or because direct stud mounting will create a ground loop which could affect the measurement. The latter is the most common reason for use of an isolated mounting. This point will be discussed later.



Mounting with the aid of a Permanent Magnet

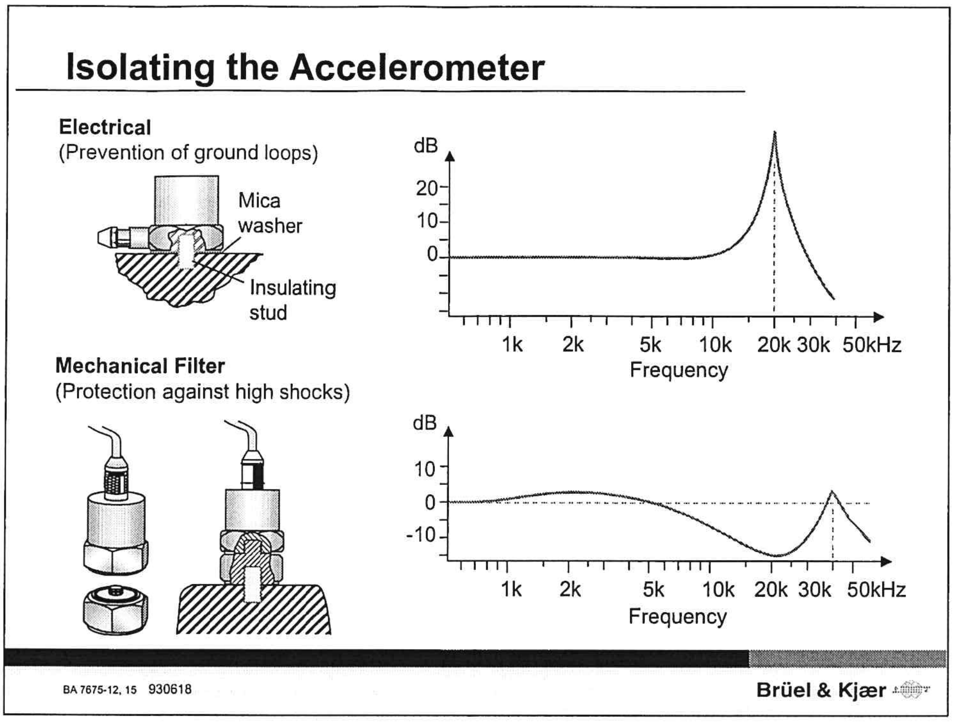
An easy and fast method of mounting the accelerometer is by using a permanent magnet which very easily can be shifted from one position to another. This is especially useful for surveying. The method is restricted to use on ferro-magnetic surfaces and the dynamic range is limited due to the limited force of the magnet. To obtain the maximum frequency range and dynamic range, the ferro-magnetic surface must be clean and flat. By fitting a self adhesive disc on the magnet it will provide electrical isolation between the accelerometer and the surface to which it is attached.

Use of a Hand Held Probe

A hand held probe with the accelerometer mounted on top is very convenient for quick-look survey work, but can give gross measuring errors because of the low overall stiffness.

Mounting the Accelerometer on a Long Rod

Where there is a need for measuring vibration at difficult-to-reach locations the accelerometer can be mounted at the end of a steel pipe or rod in a rubber ring. A slightly rounded tip is mounted onto the mounting surface of the accelerometer. Note that the response is far superior to the "hand held" probe.



Electrical Isolation

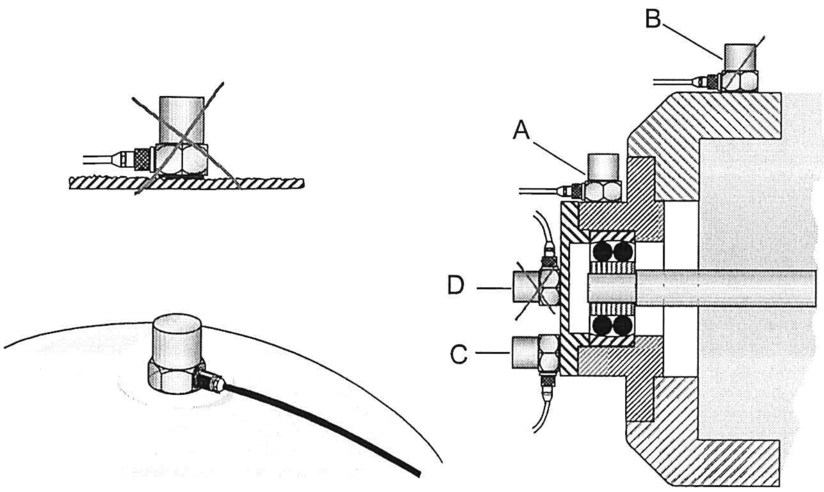
Mica washer plus insulating stud is an easy and efficient method.

Special isolated mounting pads (not shown) made from ceramic and metal brazed together are available for use at high temperatures.

Mechanical Filter

The resonance peak on the accelerometer response curve can be cut-off or reduced in amplitude with the aid of electronic filters in the measuring equipment. As most electronic filtering is made after the input stage in the preamplifier this does not prevent overloading of the input stage or the accelerometer. With the aid of a mechanical filter, which is mounted between the accelerometer and the test object, a filtering of the mechanical signal is obtained, protecting the whole measuring chain. The mechanical filter also provides electrical isolation between the accelerometer base and the mounting point.

Choosing a Mounting Position



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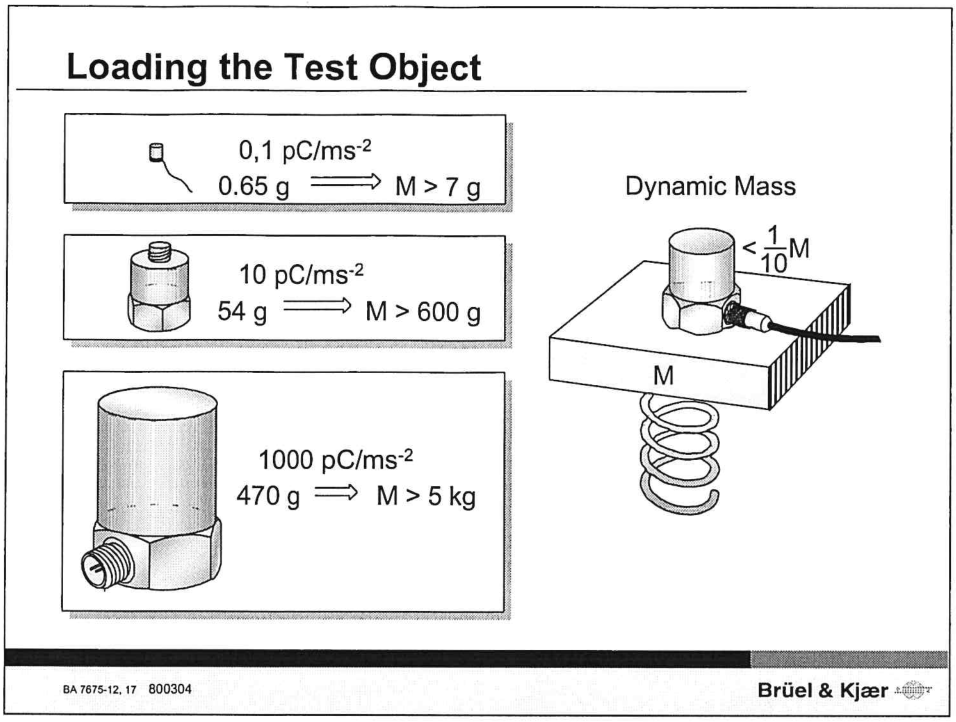
Choosing a Mounting Position for the Accelerometer

The accelerometer should be mounted so that the desired measuring direction coincides with the main sensitivity axis. Accelerometers are slightly sensitive to vibrations in the transverse direction, but this can normally be ignored as the maximum transverse sensitivity is typically only a few percent of the main axis sensitivity.

The reason for measuring vibration will normally dictate the position of the accelerometer. In the figure the reason is to monitor the condition of the shaft and bearing. The accelerometer should be positioned to maintain a direct path for the vibration from the bearing.

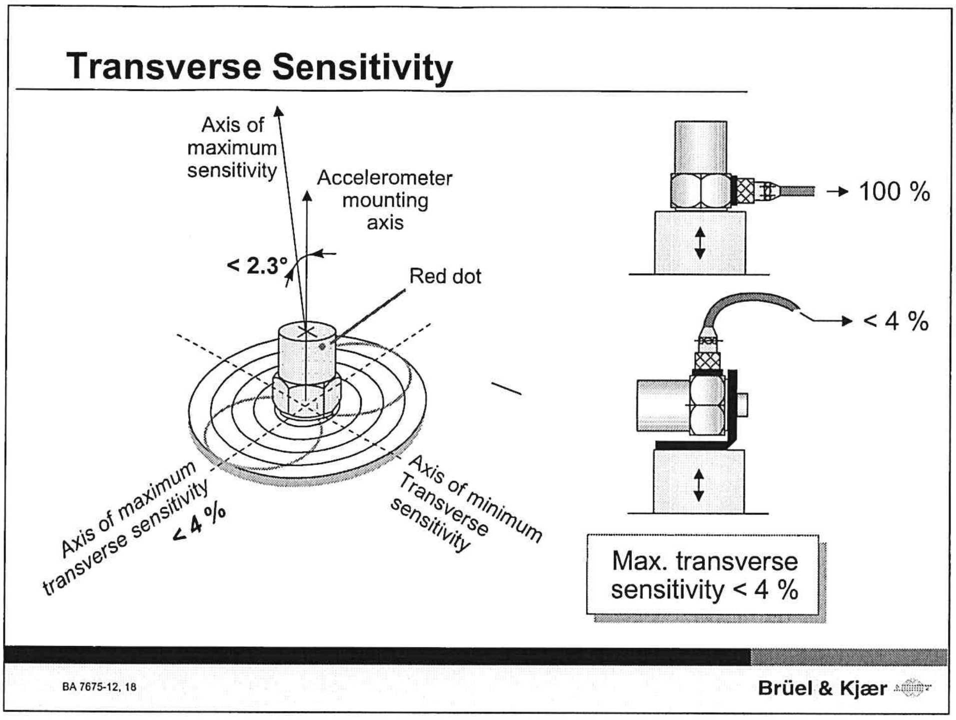
Accelerometer "A" thus detects the vibration signal from the bearing predominant over vibrations from other parts of the machine, but accelerometer "B" receives the bearing vibration modified by transmission through a joint, mixed with signals from other parts of the machine. Likewise, accelerometer "C" is positioned in a more direct path than accelerometer "D".

It is very difficult to give general rules about placement of accelerometers, as the response of mechanical objects to forced vibrations is a complex phenomenon, so that one can expect, especially at high frequencies, to measure significantly different vibration levels and frequency spectra, even on adjacent measuring points on the same machine element.



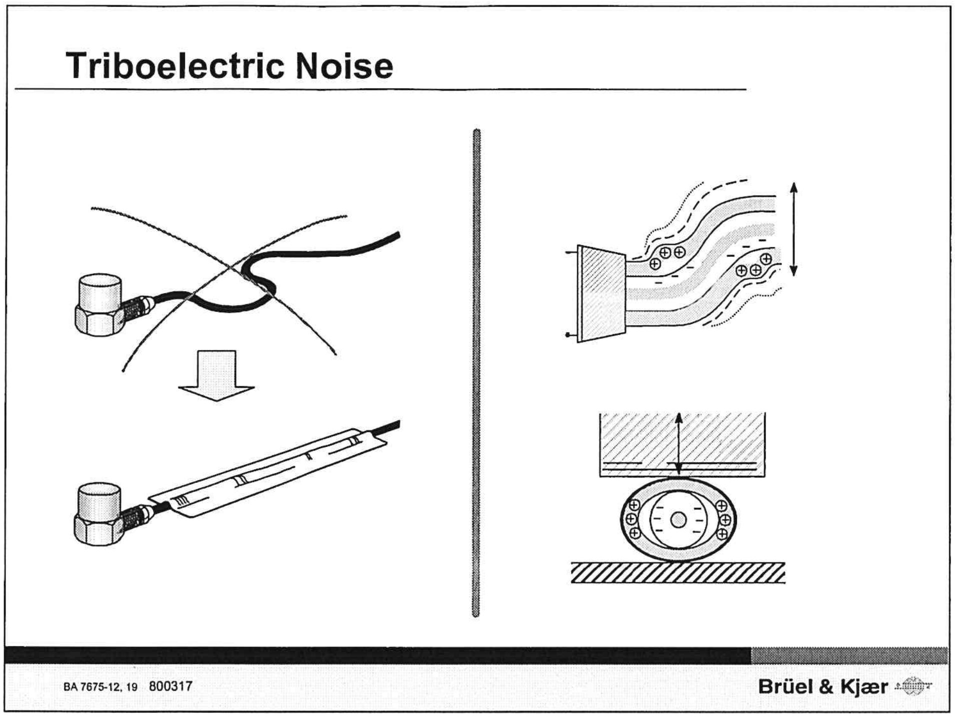
Loading the Test Object

When the accelerometer is mounted on the test object it will increase the mass of the vibrating system, and thereby influence the mechanical properties of the test object. As a general rule the accelerometer mass should be no more than one-tenth of the "local" dynamic mass of the vibrating part onto which it is mounted.



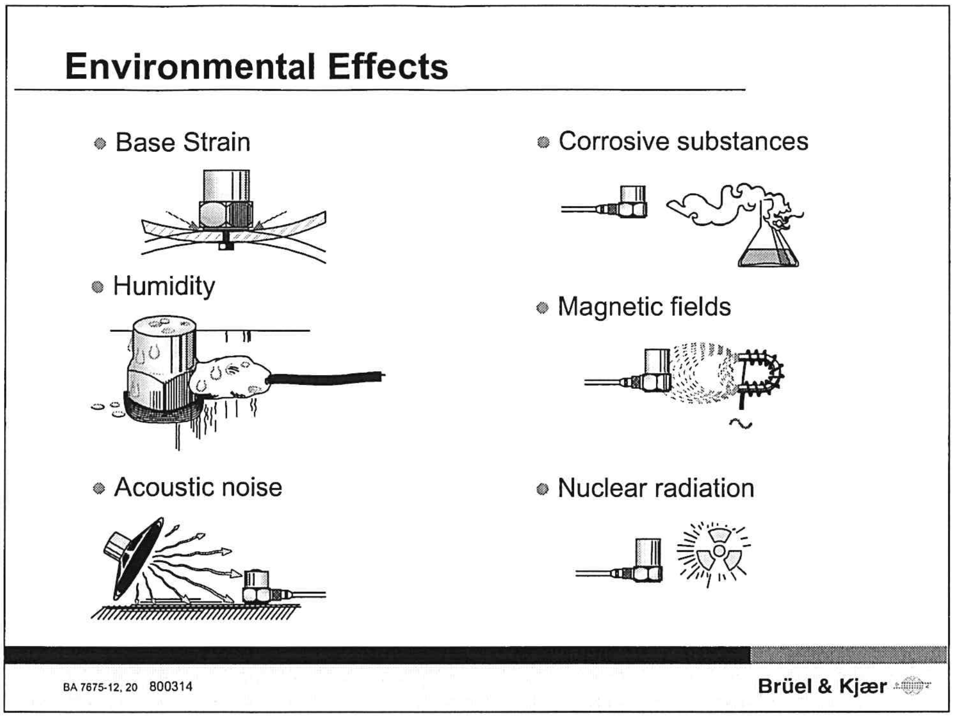
Transverse Sensitivity

The accelerometer has its main sensitivity perpendicular to the base of the accelerometer. However, it is also slightly sensitive to vibrations occurring in a direction transverse to this. In the worst case this will typically be less than 4% of the main-axis sensitivity. The direction of minimum transverse sensitivity is indicated on the accelerometer with a dot of red paint or an angle indication on the calibration chart.



Triboelectric Noise

Movement (vibration) of the accelerometer cable during use can cause the screen of the cable to be separated from the insulation around the inner core of the cable. A varying electrical field is thereby created between the conducting screen and the non-conducting insulation, causing a minute current to flow in the screen which will be superimposed on the accelerometer signal as a noise signal. This phenomenon can be prevented by using low noise (or super low noise, which has similar precautions around the center conductor) accelerometer cables and fixing them to the test object e.g. with the aid of adhesive tape near the accelerometer, and let them leave the structure at a point with minimum motion.



The Influence of Environments

Base Strain: Base strain sensitivity has been reduced by the use of a very thick base in the accelerometers. Delta Shear accelerometers are best in this respect as the elements are not in direct connection with the base.

Humidity: The accelerometer itself is sealed, so moisture can only enter the connector. In wet conditions this effect can be prevented by the use of a silicon rubber sealant.

Acoustic Noise: Has normally negligible influence on the vibration signal from the accelerometer.

Corrosive Substances: Special materials which are resistant to most corrosive substances are used in the construction of the accelerometer.

Magnetic Fields: The magnetic sensitivity is typically in the range

0.5 to 30 ms^{-2}/Tesla and thus normally not causing any problems.

Nuclear Radiation: Most accelerometers can be used under gamma radiation of 100 kRad/h up to accumulated doses of 100 MRad without significant change in characteristics. High temperature (400°C) accelerometers can be used up to 1000 MRad.

Influence of Temperature Transients: Temperature transients (rapid fluctuations) can cause an electrical output from the accelerometer, but this effect has been considerably reduced in the Delta Shear accelerometer. The charges developed on the piezoelectric material due to temperature transients are mainly developed on surfaces normal to the polarisation of the piezoelectric material and are thus not measured.

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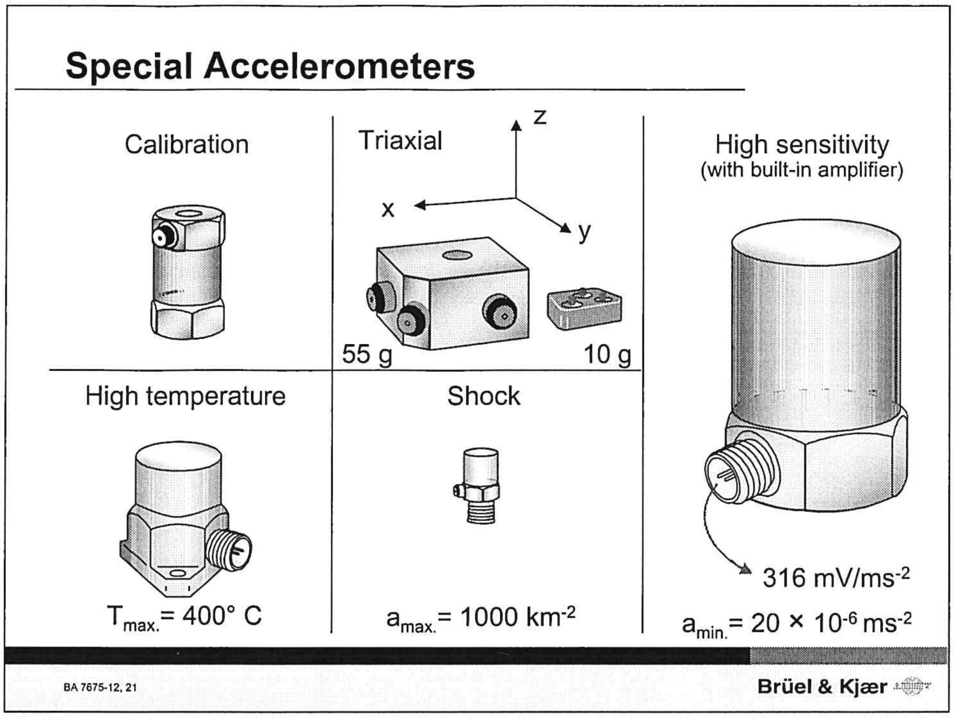

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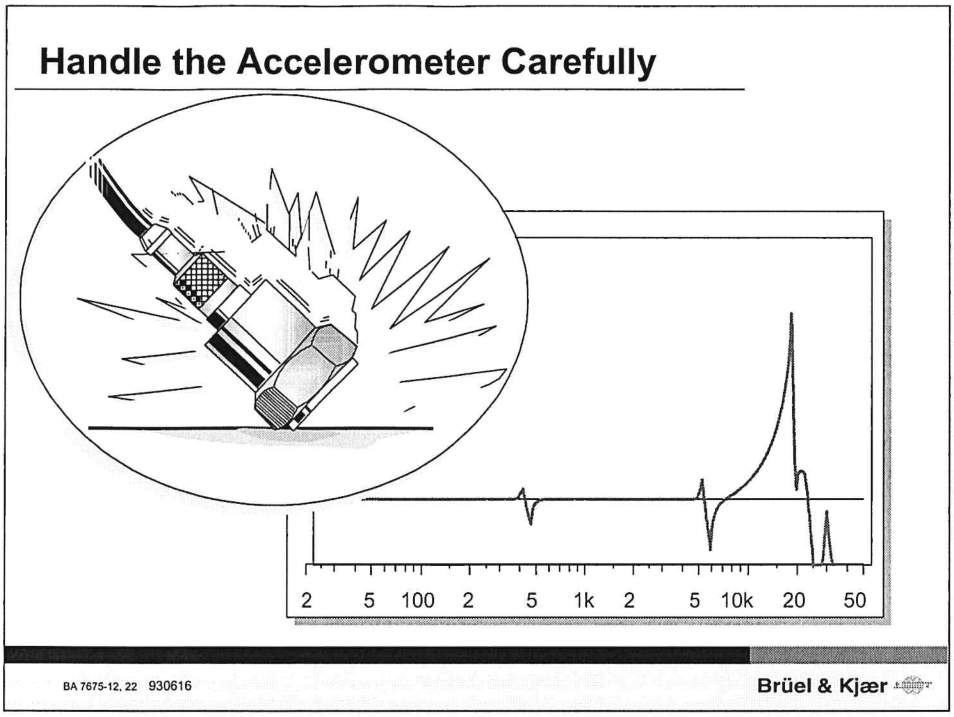
Sensitivity Change due to Temperature:

A shift in temperature will cause a small reversible change in the sensitivity of the accelerometer. For use at high temperatures it is recommended to use one of the accelerometers designed specifically for use in such conditions. The accelerometer base temperature may be kept down if a heat sink and mica washer are included in the mounting. If forced air cooling is employed check that the cooling system (fan) does not induce significant vibration.

Special Type Accelerometers

A number of accelerometers have been specially designed for specific purposes. For example, calibration references, high temperature, triaxial, high shock and very low levels as shown in the above figure.

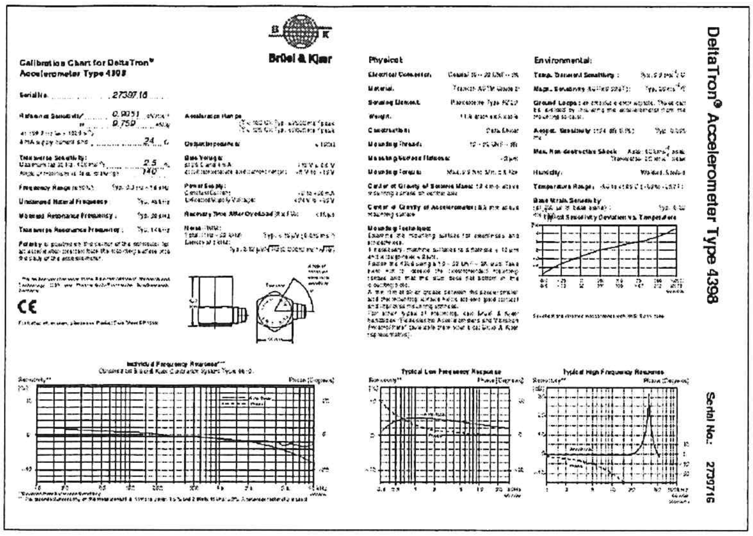


Accelerometer handling

Although most accelerometers are specified to withstand several thousand g's it is quite possible to attain such levels if the accelerometer is handled carelessly. A drop on a hard floor or a hit against a machine part might create shocks of several thousands of g. This could mean change in sensitivity or even severe damage to the accelerometer.

If it is known that the accelerometer has been subjected to such treatment it is advisable to recalibrate the accelerometer, preferably with a check of the frequency response curve.

The Calibration Chart



BA 7675-12, 23

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Calibration Chart

Each Brüel & Kjær accelerometer is supplied individually calibrated by the factory and is accompanied by a comprehensive Calibration Chart.

Two examples are shown here, one classical piezoelectric accelerometer, and one with built-in electronics.