TRAINING ON ANTAM STANDARD CODE
For TESTING OF KNAPSACK MISTERS CUM DUSTERS

Theory 10: Measurement of Vibration- concepts

(Test Code Section IV(4) and D-8, of Annex D)

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ANTAM
Asian and Pacific Network for
Testing Agricultural Machinery

Basics

- A body is said to vibrate when it describes an oscillating motion about a reference position.

- The number of times a complete motion cycle takes place during the period of one second is called the **Frequency and is measured in** Hertz (Hz).

- The motion can consists of a single component occurring at a single frequency.

- Vibration signals in practice usually consist of very many frequencies occurring simultaneously so that we cannot immediately see just by looking at the amplitude-time pattern, how many components there are, and at what frequencies they occur.

Basics

☐ These components can be revealed by plotting vibration amplitude against frequency. The breaking down of vibration signals into individual frequency components is called frequency analysis, a technique which may be considered the cornerstone of diagnostic vibration measurements.

☐ The graph showing the vibration level as a function of frequency is called a frequency spectrogram.

☐ When frequency analyzing machine vibrations we normally find a number of prominent periodic frequency components which are directly related to the fundamental movements of various parts of the machine. With frequency

☐ analysis we are therefore able to track down the source of undesirable vibration
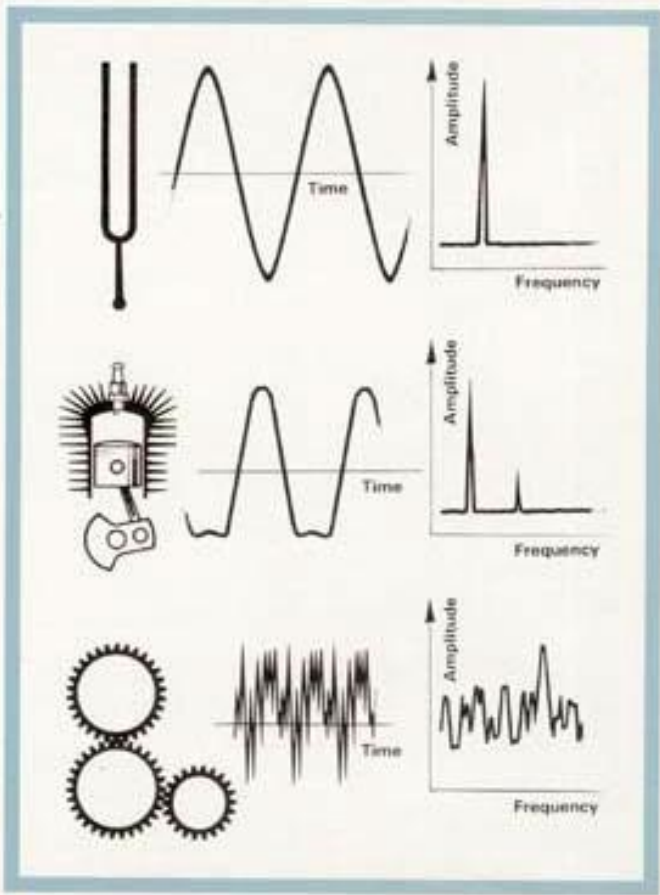
Quantifying the Vibration Level

☐ RMS (Root Mean Square) Level: Provides the most useful description of vibration levels. The square root of the integrated time-averaged squared function is related to the vibration energy and hence the vibration's damage potential. The RMS value of a sine wave is $1/\sqrt{2}$ times the value of the peak level.

☐ Peak Level: Defines the maximum level which is measured and is use full in the measurement of short duration shocks.

☐ Peak-to-peak :The **peak-to-peak value is valuable in that it indicates the** vibratory displacement of a machine part is critical for maximum stress or mechanical clearance considerations., this descriptor is rarely used.

☐ Average Level: Takes the time history of the vibration into account but there is no useful relationship between the average level and any physical quantity.
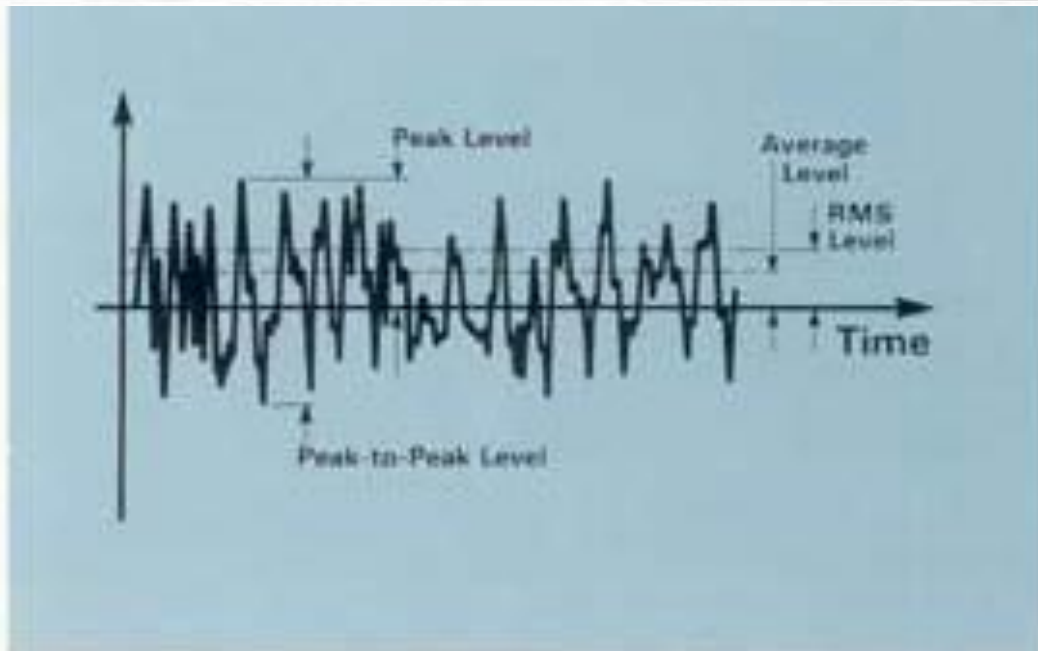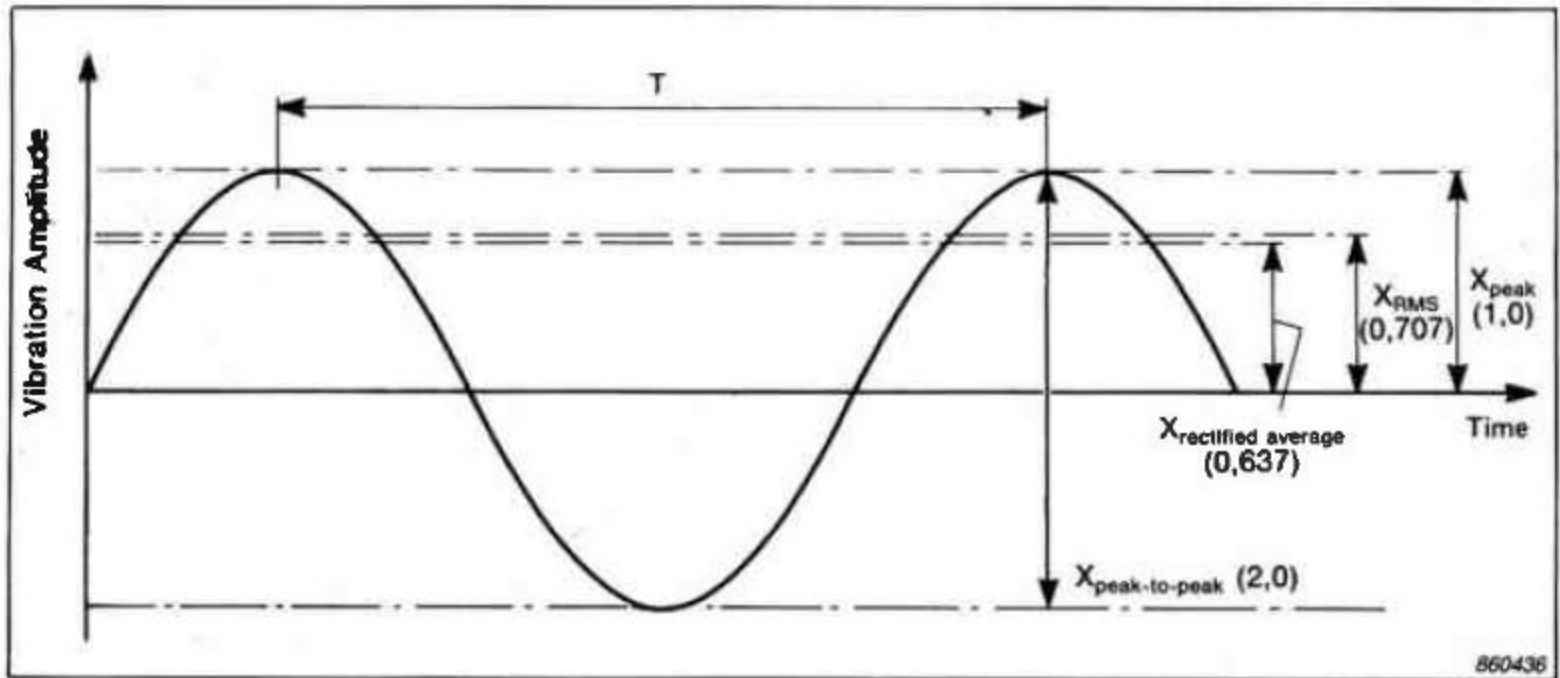
The Vibration Parameters- Acceleration, Velocity and Displacement Measuring Units

- ☐ In addition to Displacement we can also describe the Movement in terms of its velocity and its acceleration.

- ☐ The main difference is that there is a phase difference between the amplitude-time curves of the three parameters.

- ☐ For sinusoidal signals, displacement, velocity and acceleration amplitudes are related mathematically by a function of frequency and time

- ☐ If phase is neglected, as is always the case when making time-average measurements, then the velocity level can be obtained by dividing the acceleration signal by a factor proportional to frequency,

- ☐ The displacement can be obtained by dividing the acceleration signal by a factor proportional to the square of frequency.

This division is performed by electronic integrators in the measuring instrumentation. The vibration parameters are almost universally measured in metric units in accordance with ISO requirements,

By detecting vibratory acceleration with electronic integrators we can convert the acceleration signal to velocity and displacement.

Most modern vibration meters are equipped to measure all three parameters.
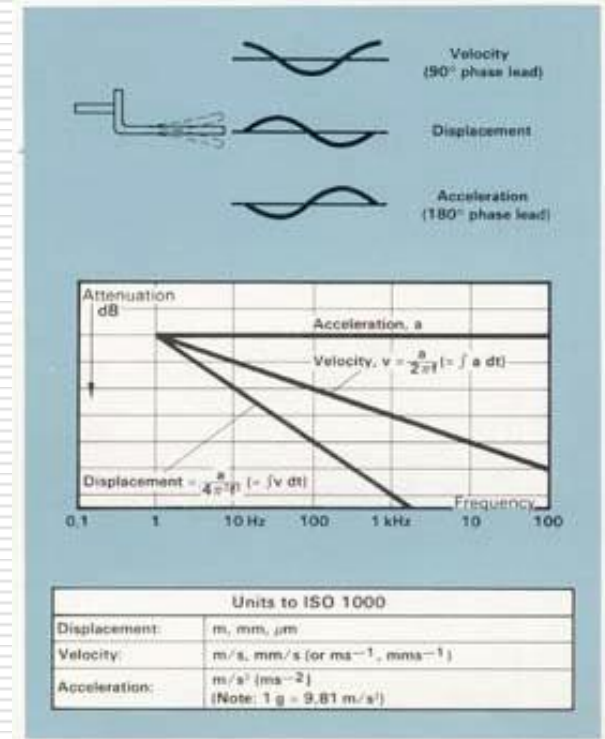
- ☐ Where a single, wide frequency band vibration measurement is made, the choice of parameter is important

- ☐ If the signal has components at many frequencies. Measurement of displacement will give the low frequency components most weight Acceleration measurements will weight the level towards the high frequency components

- ☐ Experience has shown that the overall RMS value of vibration velocity measured over the range 10 to 1000 Hz gives the best indication of a vibration's severity.

Linear and Log Scales

Linear amplitude and frequency scales are used in vibration measurements when a high resolution is needed

Piezoelectric accelerometers are capable of accurate vibration measurements over extremely wide dynamic and frequency ranges. Therefore, to obtain convenient interpretation of results the following are often required:

☐ 1. An amplitude scale which can accommodate vibration amplitudes from the lowest detectable amplitudes up to shock amplitudes, and which can also simplify the comparison of vibration amplitudes.

☐ 2. A frequency scale with the same percentage resolution over the whole width of the recording chart.

☐ The decibel (dB) is useful in vibration measurements and is Defined as the ratio of one amplitude to another and it is expressed in logarithmic form.

$$N(dB) = 10 \log_{10}\left(\frac{a^2}{a_{ref}^2}\right)$$

$$N(dB) = 20 \log_{10}\left(\frac{a}{a_{ref}}\right)$$

N   = value in decibels

a   = Amplitude

a $_{ref}$ = reference amplitude

The reference values as per ISO 1683 are

    Acceleration $=10^{-6}$ m/s^2

    Velocity $= 10^{-9}$ m/s

    Amplitude $= 10^{-12}$ m

(these values are numerically equivalent for pure sine wave at 159Hz)

The logarithmic scale is some times used to represent absolute values of amplitude, velocity and acceleration
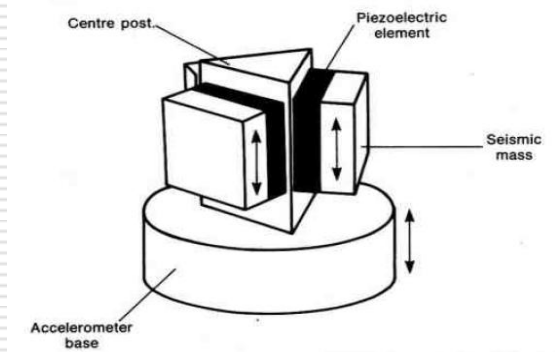
The Piezoelectric Accelerometer

- The transducer which, nowadays, is more-or-less universally
- used for vibration measurements is
- The piezoelectric accelerometer is more-or-less universally
- used for vibration measurements.
- It exhibits better all-round characteristics than any other type of vibration transducer.
- It has very wide frequency and dynamic ranges with good linearity
- throughout the ranges.
- It is relatively robust and reliable so that its characteristics remain stable over a long period of time.
- Additionally, the piezoelectric accelerometer is self-generating, so that it doesn't need a power supply.
- There are no moving parts to wear out, and finally, its acceleration
- proportional output can be integrated to give velocity and displacement proportional signals.

- The heart of a piezoelectric accelerometer is the slice of piezoelectric material, usually an artificially polarized ferroelectric ceramic, which exhibits the unique piezoelectric effect.

- When it is mechanically stressed, either in tension, compression or shear, it generates an electrical charge across its pole faces which is proportional to the applied force.
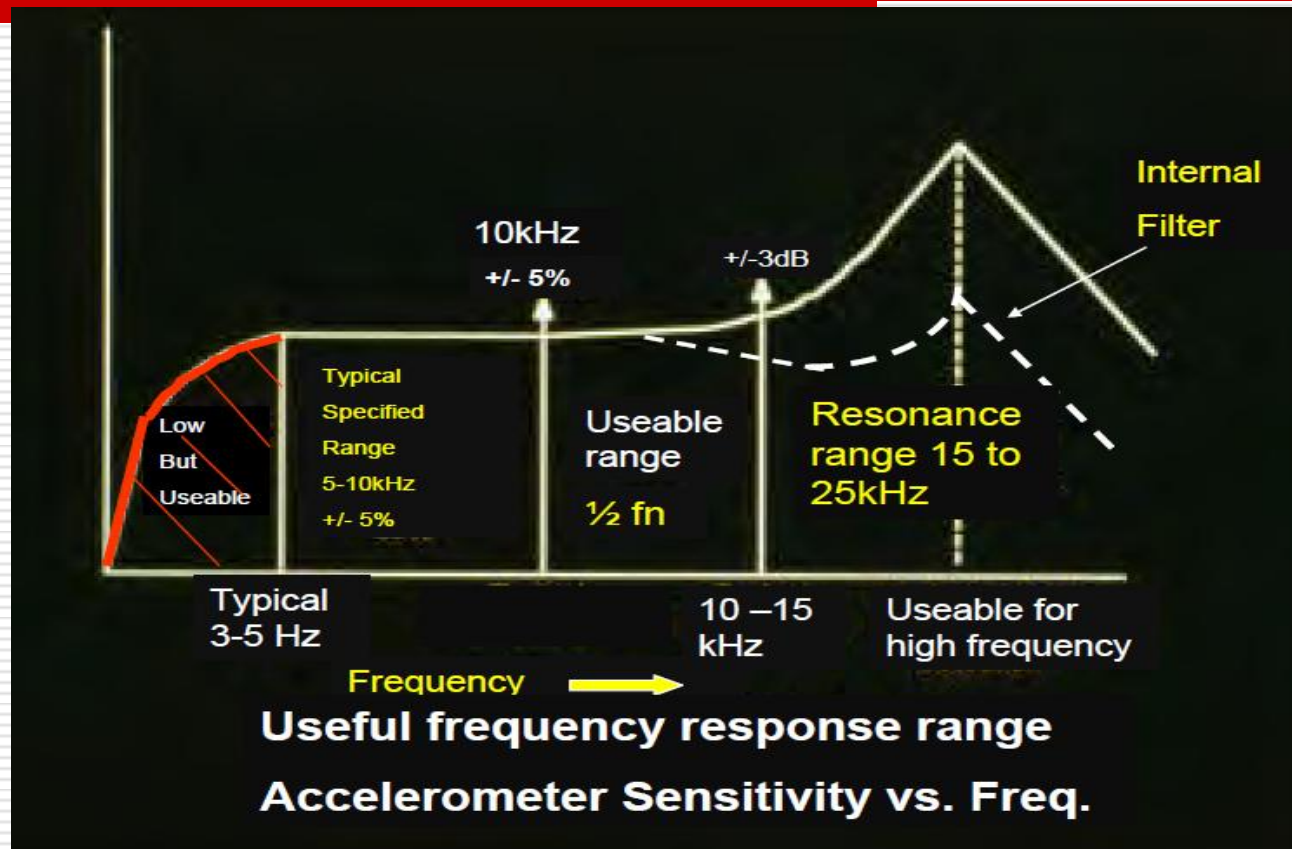
The Piezoelectric Transducer

1. Usable over very wide frequency ranges.
2. Excellent linearity over a very wide dynamic range.
3. Acceleration signal can be electronically integrated to provide velocity and displacement data.
4. Vibration measurements are possible in a wide range of environmental conditions while still maintaining excellent accuracy.
5. Self-generating so no external power supply is required.
6. No moving parts hence extremely durable.
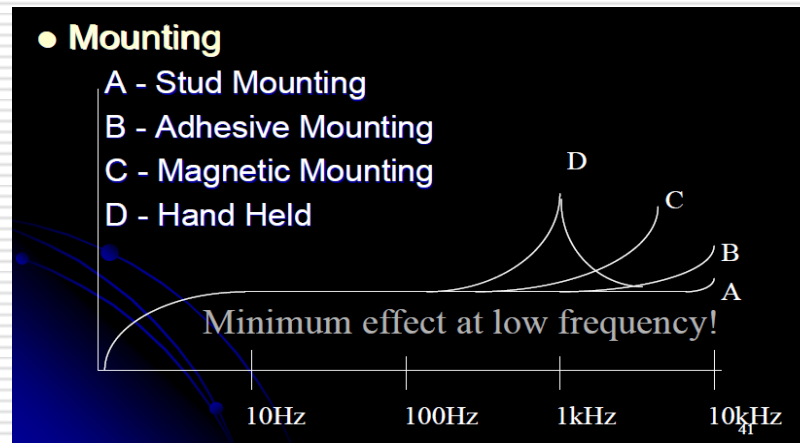7. Extremely compact plus a high sensitivity to mass ratio.

Displacement between the base and the seismic masses increases when the forcing frequency becomes comparable to the natural resonance frequency of the accelerometer Consequently the force on the piezoelectric elements and the electrical output from the accelerometer also Increase as the piezoelectric elements exhibit constant force sensitivity.The increase in electrical output of an accelerometer near its response frequency is attributable entirely to the natural Resonance of the accelerometer
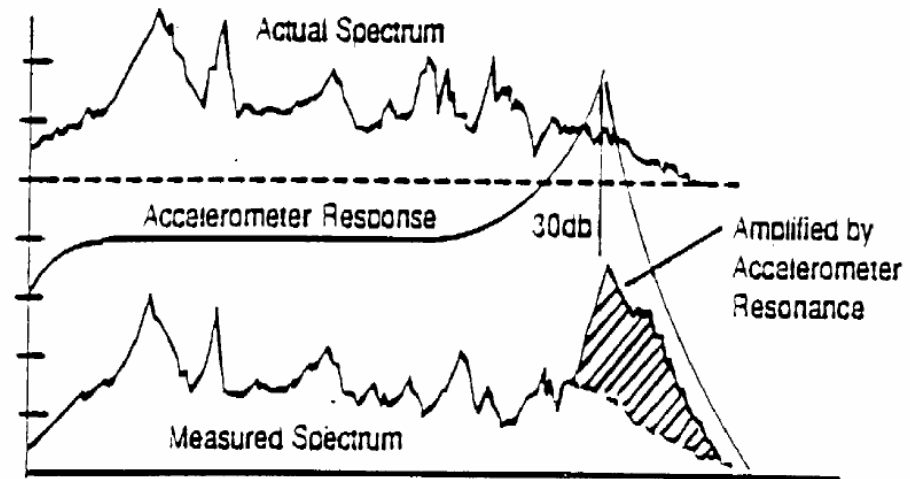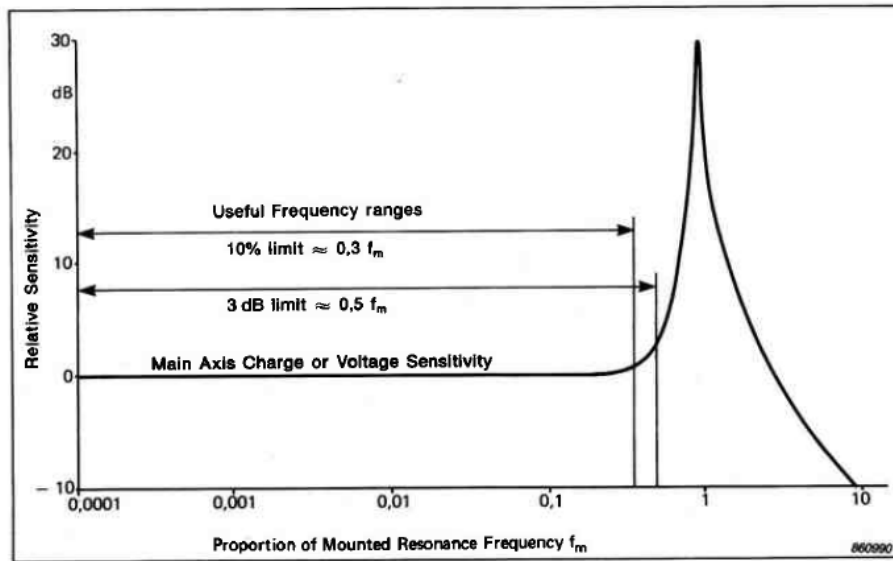
the natural frequency of the seismic mass-spring system and is defined as the mounted resonance frequency, ω_m, of the accelerometer. The mounted resonance frequency is a property of the accelerometer seismic mass spring system.

Frequency Response of Piezoectric Transducers

Useful frequency response range
Accelerometer Sensitivity vs. Freq.

Mounting techniques and response

Left figure: Relative Sensitivity (dB) vs Proportion of Mounted Resonance Frequency f_m.

- Useful Frequency ranges
- 10% limit ≈ 0,3 f_m
- 3 dB limit ≈ 0,5 f_m
- Main Axis Charge or Voltage Sensitivity

860990

Right figure:
- Actual Spectrum
- Accelerometer Response — 30db
- Measured Spectrum
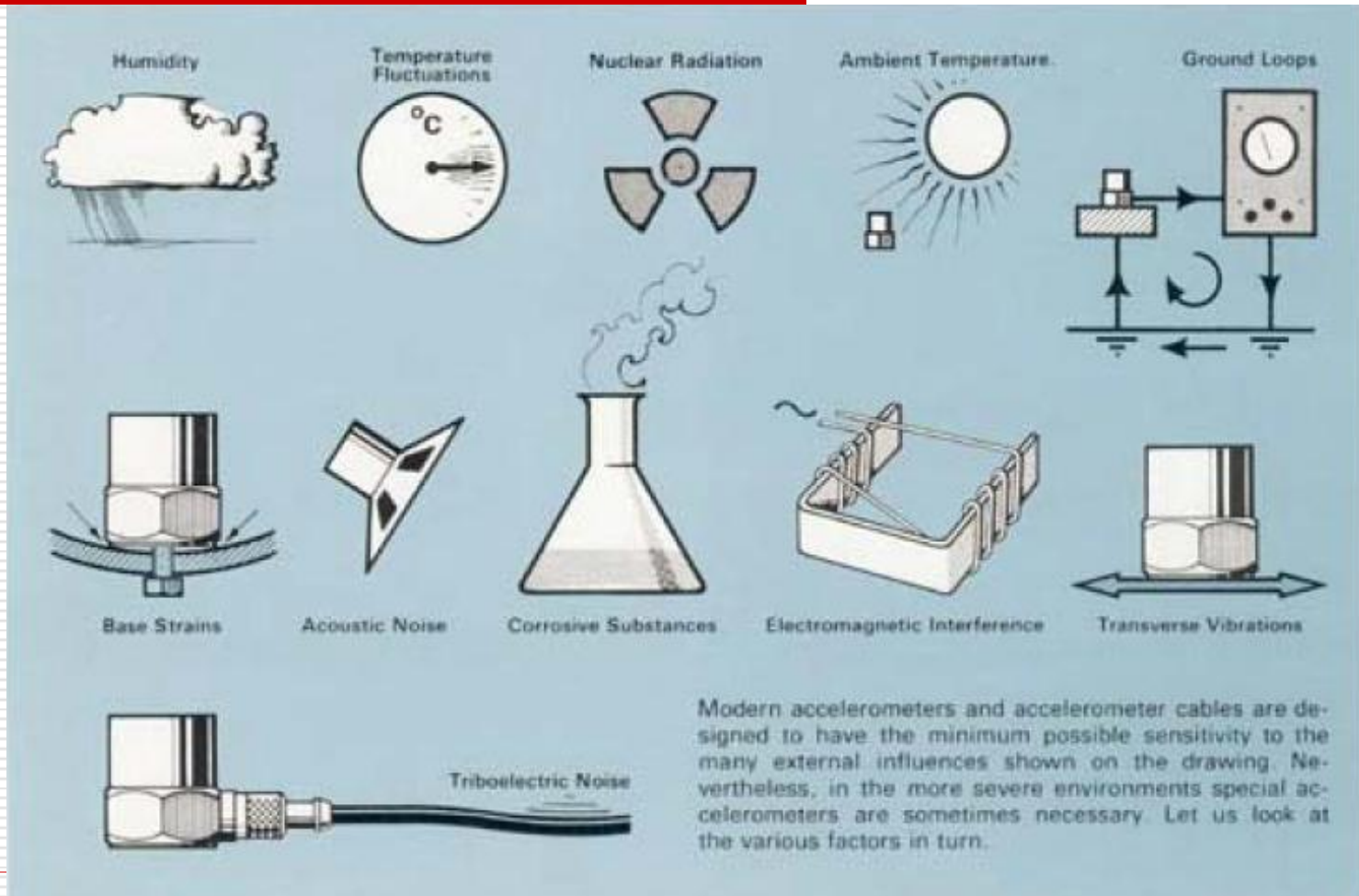- Amplified by Accelerometer Resonance

Linearity

The piezoelectric accelerometer is an extremely linear device over a very wide dynamic range because of the linear performance of the piezoelectric Elements over a wide dynamic range. In theory the accelerometer is linear down to zero acceleration

Environmental Factors to be considered

Humidity   Temperature Fluctuations   Nuclear Radiation   Ambient Temperature   Ground Loops

°C

Base Strains   Acoustic Noise   Corrosive Substances   Electromagnetic Interference   Transverse Vibrations

Triboelectric Noise

Modern accelerometers and accelerometer cables are designed to have the minimum possible sensitivity to the many external influences shown on the drawing. Nevertheless, in the more severe environments special accelerometers are sometimes necessary. Let us look at the various factors in turn.

Vibration Analysis

- The vibration meter will give us a single vibration level measured over a wide frequency band. In order to reveal the individual frequency components making up the wideband signal we perform a frequency analysis.

- For this purpose we use a filter which only passes those parts of the vibration signal which are contained in a narrow frequency band. The pass band of the filter is moved sequentially over the whole frequency range of interest so that we obtain a separate vibration level reading for each band.

- The filter can consist of a number of individual, contiguous, fixed-frequency filters which are frequency scanned sequentially by switching,

Vibration Measurement Instrumentation

Calibrator With Single Axis Accelerometer

Accelerometer for Seat Vibration Measurements