BRITISH STANDARD

BS ISO 5348:1998

Mechanical vibration and shock — Mechanical mounting of accelerometers

ICS 17.160

National foreword

This British Standard reproduces verbatim ISO 5348:1998 and implements it as the UK national standard. It supersedes BS 7129:1989 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GME/21, Mechanical vibration and shock, to Subcommittee GME/21/2, Vibration and shock measuring instruments and test equipment, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ISO title page, page ii, pages 1 to 11 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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INTERNATIONAL STANDARD

ISO 5348

Second edition
1998-05-15

Mechanical vibration and shock — Mechanical mounting of accelerometers

Vibrations et chocs mécaniques — Fixation mécanique des accéléromètres

Reference number
ISO 5348:1998(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 5348 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock, Subcommittee SC 3, Use and calibration of vibration and shock measuring instruments*.

This second edition cancels and replaces the first edition (ISO 5348:1987), which has been technically revised.

Descriptors: Vibration, mechanical shock, accelerometers, characteristics, mountings.

Introduction

The method most commonly used for determining the vibratory motion, v_S, of a structure or body S is that using an electromechanical transducer T.

Vibration-monitoring transducers fall into two broad classes: contacting and non-contacting transducers. Non-contacting structural response transducers are placed in close proximity to the structure and include such generic types as eddy-current probes and optical proximity probes. Contacting transducers are placed in mechanical contact with the structural system and include such generic types as piezoelectric and piezoresistive accelerometers and seismic velocity transducers. This International Standard is concerned with the contacting type of accelerometers which currently are in wide use. The concern with using such transducers is that the mechanical coupling between the accelerometer and the test structure may significantly alter the response of the accelerometer, the structure, or both. This International Standard attempts to isolate parameters of concern in the selection of a method to mount the accelerometer onto the structure.

This International Standard deals with accelerometers which are connected to the surface of the structure in motion by means of a mechanical mounting F (see Figure 1).

The information supplied by such a transducer is the electric signal, u, generated by the action of its own motion, v_T. The information desired is the vibratory motion, v_S, at a specified location on the structure S.

The electric signal, u, generated by the transducer deviates from what it would have been, if that particular accelerometer effectively measured the vibratory motion, v_S, of the structure, owing to non-ideal transfer of motion from S to the sensitive elements of the accelerometer T.

Deviations may also occur owing to misalignment of the sensitive axis of the transducer, base bending, temperature transients, mounting torque and cable whip.

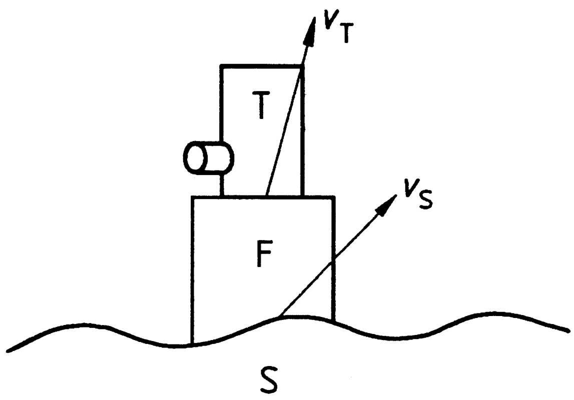
The mechanical mounting will change the useful frequency range for a given accuracy with regard to amplitude as well as phase response (see **5.4.5**).

1 Scope

This International Standard describes the mounting characteristics of accelerometers to be specified by the manufacturer and makes recommendations to the user for mounting accelerometers.

Application of this International Standard is limited to the mounting of accelerometers which are mounted on the surface of the structure in motion, as illustrated in the simplified diagram shown in Figure 1.

It is not applicable to other types of transducers, such as relative motion pick-ups.



Key

S is the structure;
F is a means of mounting;
T is an accelerometer;
v_s is vibratory motion of the structure;
v_T is vibratory motion of the accelerometer.

Figure 1 — Accelerometer mounting

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2041:1990, *Vibration and shock — Vocabulary.*

ISO 2954:1975, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity.*

ISO 5347-14:1993, *Methods for the calibration of vibration and shock pick-ups — Part 14: Resonance frequency testing of undamped accelerometers on a steel block.*

ISO 5347-22:1997, *Methods for the calibration of vibration and shock pick-ups — Part 22: Accelerometer resonance testing — General methods.*

ISO 8042:1988, *Shock and vibration measurements — Characteristics to be specified for seismic pick-ups.*

3 Definitions

For the purposes of this International Standard, the terms and definitions given in ISO 2041 apply.

4 Characteristics to be specified by manufacturers of accelerometers

The manufacturer shall specify the following characteristics:

a) mounting-surface characteristics pertinent to the mounting device(s) furnished with the accelerometer, e.g. surface finish roughness, surface flatness, hole perpendicularity and tap class;

b) the geometrical dimensions of the accelerometer including

— the position of the centre of gravity of the accelerometer as a whole,

— the position of the centre of gravity of the seismic mass of the accelerometer;

c) the mounting technique used during calibration;

d) the recommended and maximum (i.e. for less than 2 % change in the useful frequency range) mounting torque;

e) temperature limitations of the accelerometer and fastening device;

f) pertinent mechanical characteristics, i.e.

— total mass,

— material of base,

— the lowest unmounted resonance frequency of the accelerometer,

— the frequency response characteristic under well-defined mounting conditions, describing the object on which the transducer is mounted in terms of mass, material and dimensions,

— the maximum transverse sensitivity, and the frequency at which it was determined;

g) a description of the various fastening devices provided for the accelerometer, i.e.

— diameter,

— thread,

— material;

h) the frequency response curves of the accelerometer with the type of mechanical mounting recommended by the manufacturer and the effect of special mounting devices supplied with the accelerometer, in particular

— axial stiffness, with account taken of the state of the surface of the structure in contact with the accelerometer and the tightening torque of the accelerometer,

— transverse deflection stiffness, on the same basis.

For other characteristics to be specified by the manufacturer, refer to ISO 8042.

5 Consideration in the selection of a mounting method

5.1 General considerations

5.1.1 *Procedures*

An accelerometer will achieve optimal performance only if the following general procedures are followed:

a) the accelerometer shall perform as nearly as possible the same motion as the structure under test at the accelerometer attachment;

b) the motion of the structure shall be changed as little as possible by the addition of the accelerometer;

c) the ratio of the signal from the accelerometer to the motion of the accelerometer shall not be distorted by operating too near to its mounted fundamental resonance frequency.

5.1.2 ***Conditions***

In order to achieve these ideal conditions, it is necessary to ensure that:

a) the accelerometer and its mounting are as rigid and firm as possible (the mounting surfaces shall be as clean and flat as possible);

b) the mounting introduces minimum distorting motions of its own (for example, simple symmetrical mountings are best);

c) the mass of the accelerometer and mounting are small in comparison with that of the dynamic mass of the structure under test (see ISO 2954).

5.2 Specific considerations

5.2.1 ***Frequency range of operation***

The accelerometer shall be used well below its fundamental resonance frequency. If it is possible to use the manufacturers' recommended mounting, then operation at frequencies not greater than 20 % of their quoted mounted resonance should, in the case of undamped accelerometers (resonance magnification factor Q greater than 30 dB), ensure in most cases that errors of only a few percent on the amplitude response occur. If an estimate of the approximate error is required, it may be made on the basis of an equivalent linear spring-mass system with a given value of damping.

NOTE For single shock measurements, one may expect errors of only a few percent if the mounted fundamental resonance frequency is ten times greater than the inverse of the pulse duration.

5.2.2 ***Mounting torque***

When screw thread mounting is used, the mounting torque shall be as recommended by the manufacturer.

5.2.3 ***Cables***

Stiff cables can cause case strain when used with accelerometers with axial connectors. Careful clamping of the cables is required to avoid such problems (see Figure 2).

Loose cables may introduce tribo-electric effects for piezo-electric type transducers.

5.3 Determination of the mounted fundamental resonance frequency

It is very useful, though at times difficult in practice, to determine accurately the mounted fundamental resonance frequency of the accelerometer mounted on the structure under test. The following method may be of use in finding the approximate resonance, thus ensuring that an adequate margin exists between it and the test frequency.

5.3.1 ***Vibration excitation method***

A suitable steel reference block with well-defined shape and surface finish is recommended, e.g. a stainless steel block of mass 180 g. The motion of the reference block is monitored close to the mounting surface of the accelerometer being tested using an accelerometer with a resonance frequency higher than that of the first bending mode of the steel block itself. The excitation force can be generated electrodynamically. The influence of the quality of mounting surfaces and materials may be investigated by introducing typical samples between the steel surface and the accelerometer being tested (see Figure 3). For common mountings and representative mounted frequency curves, see Figure 5 to Figure 10.

For the method of determining the fundamental (resonance) frequency, see ISO 5347-14 and ISO 5347-22.

NOTE The frequency response curves given in the figures are typical; they are strongly influenced by the parameters that are indicated in the figures.

5.3.2 ***Shock excitation methods***

The ballistic pendulum, the drop test and a simple hammer blow are three ways of using shock excitation. In the first, the accelerometer is attached to an anvil mass suspended as a pendulum while a second hammer mass, similarly suspended, is used to provide the blow. In the drop test, the accelerometer is attached to a hammer which is guided in its vertical fall onto a stationary anvil to provide the shock. The attachment of the accelerometer to the mass shall be similar to the actual test body attachment. While it may be impossible to represent the test body by the mass of the anvil or hammer, it shall be made of the same material and of sufficient size to be a reasonable representation of the test body with regard to the stiffness. The hammer blow applied near the mounted accelerometer on the actual structure may provide the necessary information, if structural resonance in the measuring object can be disregarded.

The accelerometer output produced by the shock under suitable conditions will have the resonance frequency superimposed (see Figure 4). Some experimentation is required with the energy of shock (i.e. the height from which the mass is released) and the stiffness of the impact surface (for example, steel or lead lined) to obtain a suitable period of impact to display the resonance effect. Care shall also be taken to see that the lowest resonance is excited during the shock. The use of suitable single-event recorder storage device or photographing technique enables the frequency of the resonance ripple to be determined. These methods are particularly suited for high frequencies.

Repeated well-defined shocks may give additional information in the stability of the mounting.

5.4 Recommendations for particular types of mountings

5.4.1 *General*

The mounting surface shall be carefully examined for contamination and smoothness and, if necessary, it shall be machined flat. Any lack of alignment between the sensitive axis of the accelerometer and the direction of measurement shall be minimized, as otherwise this will lead to errors similar to those introduced by transverse sensitivity. These errors will be particularly large if the transverse motion is much greater than the axial motion.

The condition of the mounting surface and method of mounting should be stated in any report.

The recommended mounting methods for the transducer should be followed in order to make the manufacturer's data applicable.

An overview of the criteria that affect selection of mounting methods, based on best practices, is given in Table 1.

Table 1 — Criteria that affect selection of mounting methods (based on best practices)

	Resonance frequency	Temperature	Mass of transducer and stiffness of mounting	Resonance magnification factor Q	Importance of surface preparation
Stud	●	●	●	●	●
Methylcyano acrylate cement	●	●	●	●	◑
Beeswax	◑	○	◑	●	●
Double-sided tape	○	◑	○	○	●
Quick mount	◑	●	◑	◑	◑
Vacuum mounted	◑	●	●	◑	◑
Magnet	◑	●	○	○	●
Hand held	○	○*)	○	○	○

*) Depends entirely on distance between hand and measured surface.

Key: ● high ◑ average ○ poor

5.4.2 ***Stud mounting***

5.4.2.1 Surfaces shall be clean, flat and machined smooth to manufacturer's tolerances when specified. The axes of the stud mounting holes shall be normal to the mounting surface.

5.4.2.2 The manufacturer's recommended mounting torque should be used to obtain a firm fixing without damaging the accelerometer.

5.4.2.3 A thin film of oil or grease between the surfaces helps to achieve good contact and thus maximum stiffness (see Figure 5).

5.4.2.4 The stud shall not bottom in the mounting holes as rigidity may be lost owing to a small gap between the surfaces.

5.4.3 ***Cementing***

This method shall be used where the structure under test cannot be drilled, or where electrical isolation of the accelerometer is necessary, or where the surface flatness is insufficient. A cementing stud, threaded at one end and with a flat disc at the other end for cementing to the structure, is often used.

5.4.3.1 The surface shall be cleaned to the cement manufacturer's recommendations.

5.4.3.2 A thin layer of cement shall be used as this represents a stiffer spring.

5.4.3.3 Hard cements of the catalytic or thermosetting variety shall be used. Solvent-drying cements tend to remain soft internally and thus lower the resonance frequency (see Figure 6).

NOTE The mounted resonance frequency, f_c, can be estimated by the formula:

$$f_c = \frac{1}{2\pi}\sqrt{\frac{|K_c|}{m}}$$

where

- K_c is the complex compressional stiffness of the cement bond, and
- m is the total mass of the transducer and any mounting fixtures.

The complex compressional stiffness, K_c, of the cement bond can be estimated by the formula:

$$K_c = E(1 + i\eta)A/t$$

where

- E is the elastic (i.e. Young's) storage modulus of the cement,
- η is the elastic loss tangent of the cement,
- A is the area of the bond, and
- t is the thickness of the bond.

The shear resonance of the bond can also be estimated using the formula:

$$f_s = \frac{1}{2\pi}\sqrt{\frac{|K_s|}{m}}$$

where K_s is the complex shear stiffness of the bond.

The shear stiffness can be estimated by the formula:

$$K_s = G(1 + i\beta)A/t$$

where

- G is the shear storage modulus of the cement, and
- β is its shear loss tangent.

Generally, to increase the operating frequency band of the mounted accelerometer the cement should be lightly damped (i.e. η or β less than 0,01), hard (i.e. high E and G values) and the bond should be thin.

5.4.4 ***Mounting fixtures***

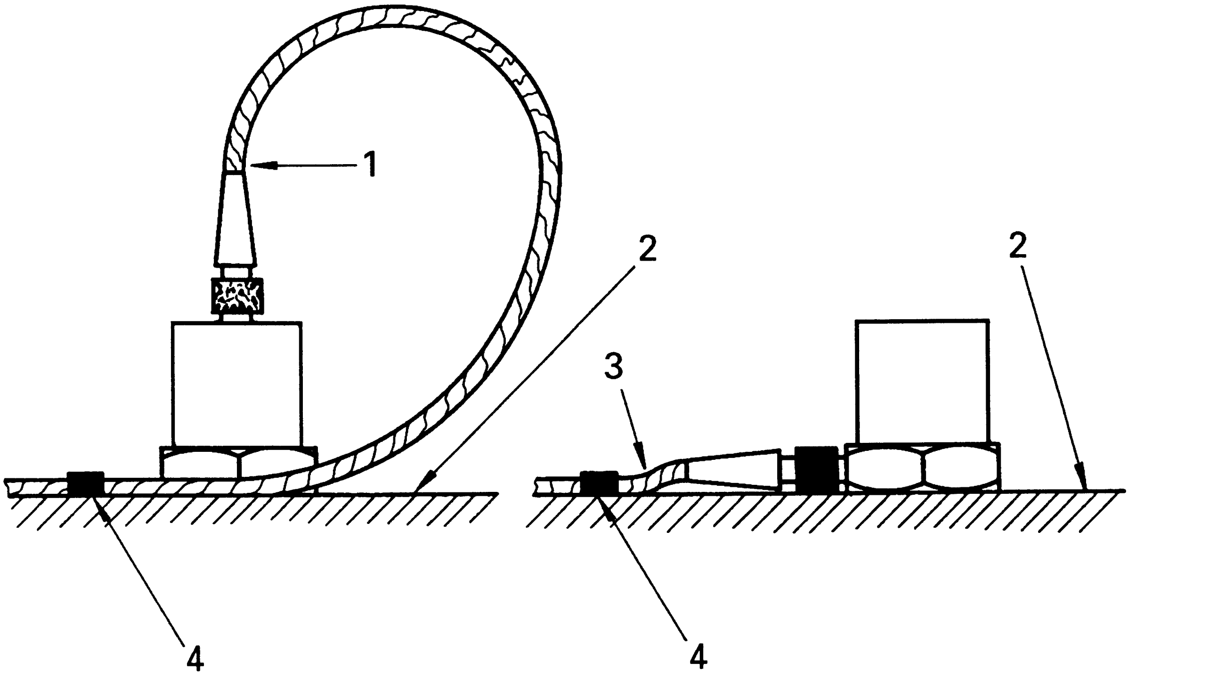
Mounting fixtures, including electrical isolating studs, should be constructed as a stiff, low-mass element with low moment of inertia and, preferably, symmetrical about the sensitive axes.

Brackets shall be avoided if possible. When necessary, it is recommended that a small stiff metal cube be used, rigidly mounted to the structure, with machined surfaces drilled and tapped to accept stud mounting.

If the use of a complicated bracket is unavoidable, an investigation of its vibration modes and frequencies is desirable.

5.4.5 ***Miscellaneous mountings***

Many routine tests can be successfully carried out by fixing the accelerometer with a thin layer of hard setting wax (see Figure 10), by using double-sided pressure sensitive tape (see Figure 7), by using magnetic attachment (see Figure 9), by using quick-fit mounting attachment (see Figure 11) or by using vacuum mounting (see Figure 12). These methods are severely restricted in amplitude and frequency range. In doubtful cases, the fundamental resonance frequency and amplitude range shall be investigated experimentally. Hand-held accelerometers are not generally recommended (see Figure 8).

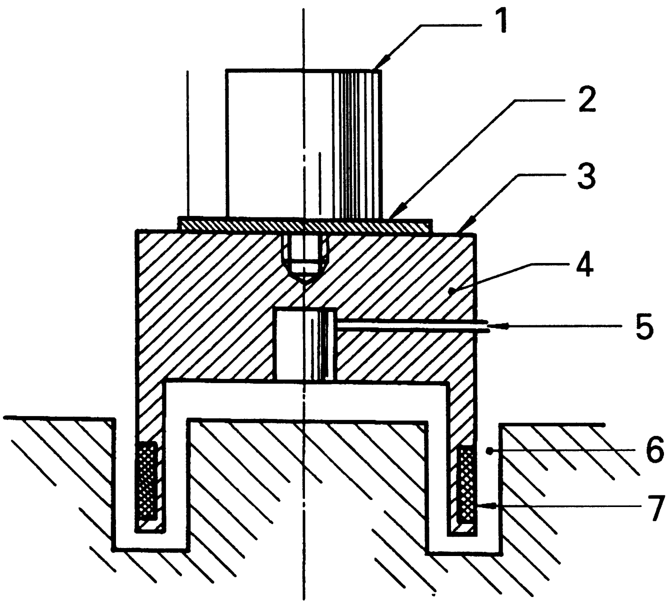


a) Accelerometer with axial connector

b) Accelerometer with radial connector

1 Do not stress
2 Vibrating surface
3 Do not stress
4 The cable is fixed to the vibrating surface

Figure 2 — Accelerometers with axial and radial connectors



1 Accelerometer
2 Test surface
3 Polished reference surface
4 Steel reference block
5 Reference accelerometer
6 Magnetic field
7 Drive coil

Figure 3 — Accelerometer test arrangement

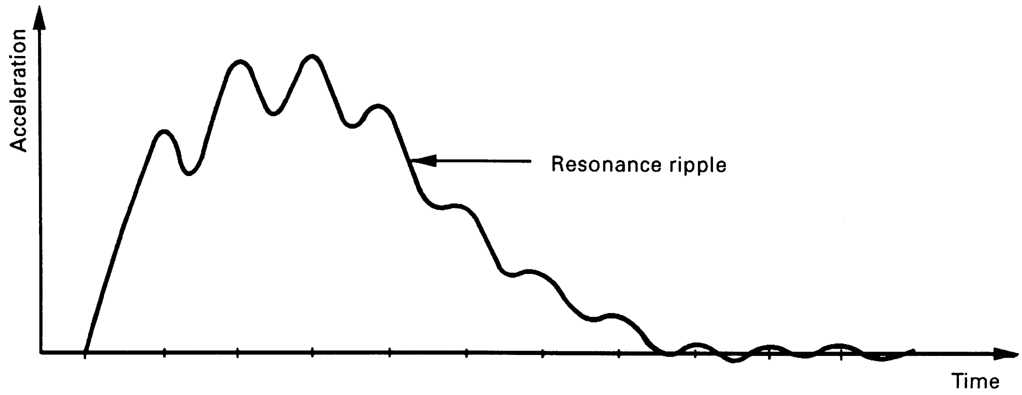


Figure 4 — Accelerometer response to shock

Response influenced by: perpendicularity of mounting
surface flatness and surface roughness
mounting torque

Torque used for the test

M5 : 1,8 N·m
M3 : 0,6 N·m

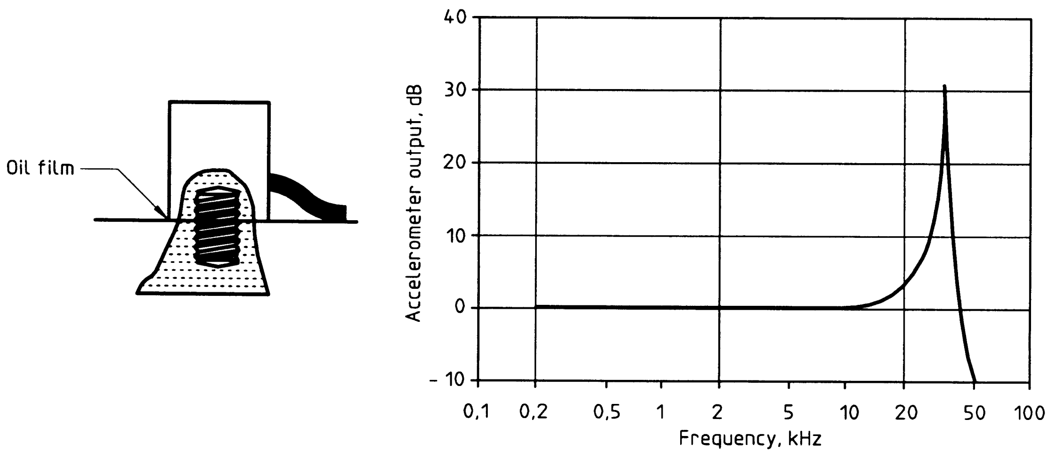


Figure 5 — Typical frequency response of a representative stud-mounted accelerometer with oil film relative to the absolute acceleration of the structure at its attachment

Response influenced by: storage and mixture of cement
contamination by oil or grease
thickness of bond
complex elastic modulii of cement
temperature

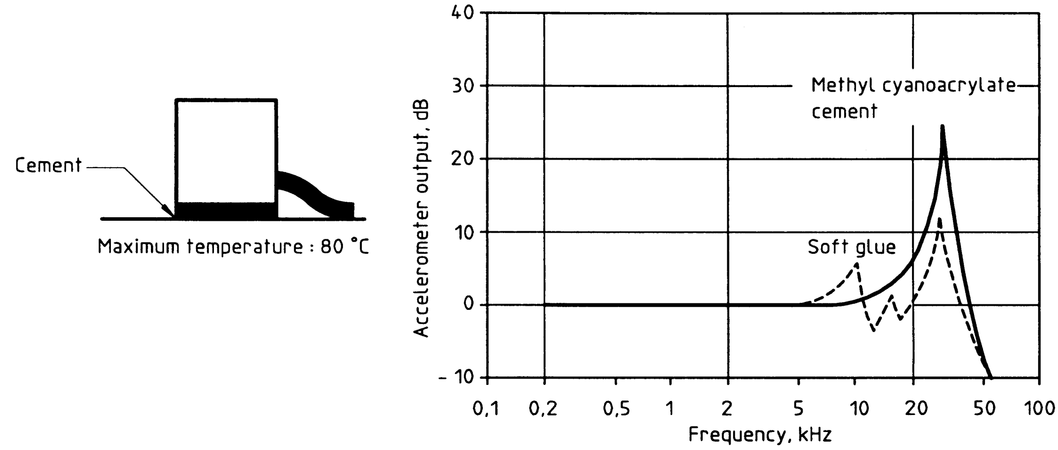
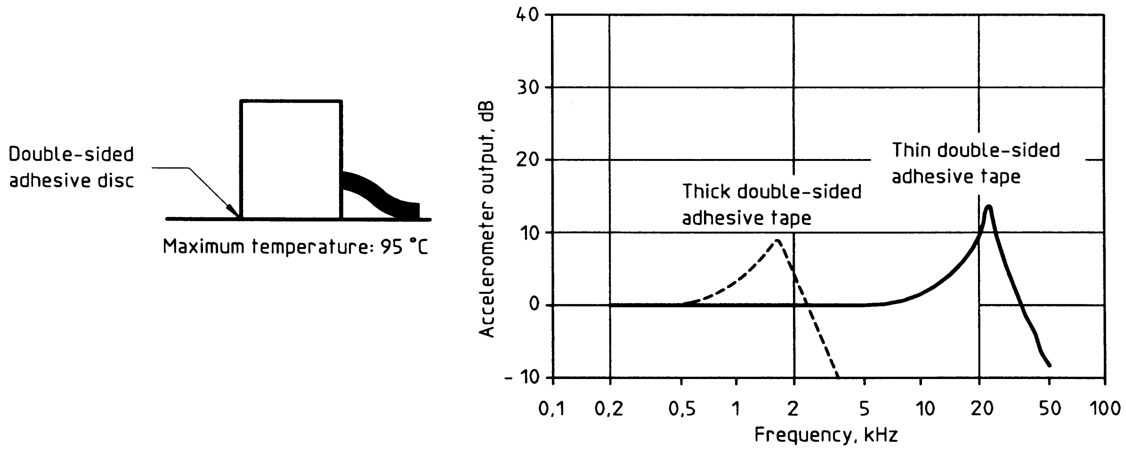


Figure 6 — Typical frequency response of a representative cement-mounted accelerometer relative to the absolute acceleration of the structure at its attachment

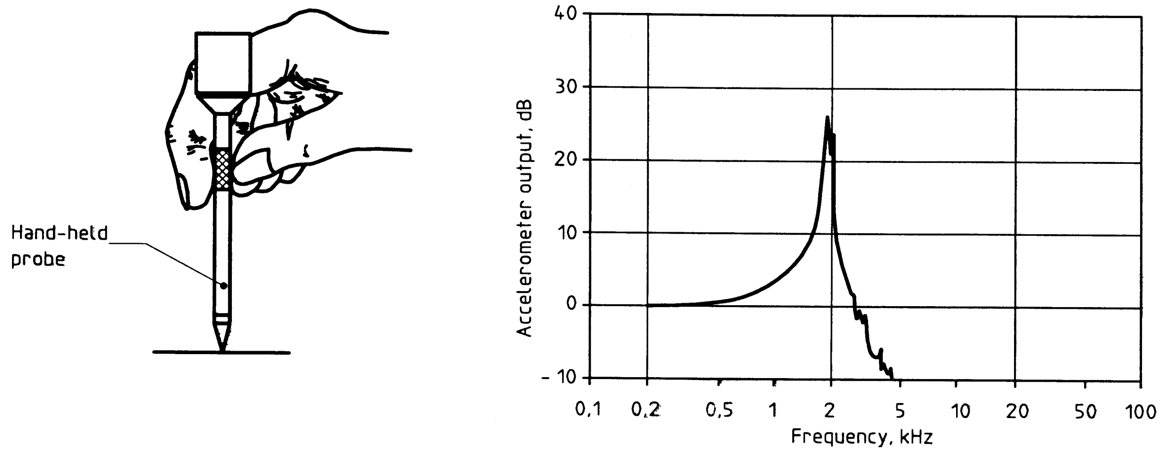
Response influenced by: sufficient surface contact
flatness of base and surface
material
complex elastic modulii of tape



NOTE Restricted in use, see **5.4.5**.

Figure 7 — Typical frequency response of a representative accelerometer mounted by double-sided adhesive tape relative to the absolute acceleration of the structure at its attachment

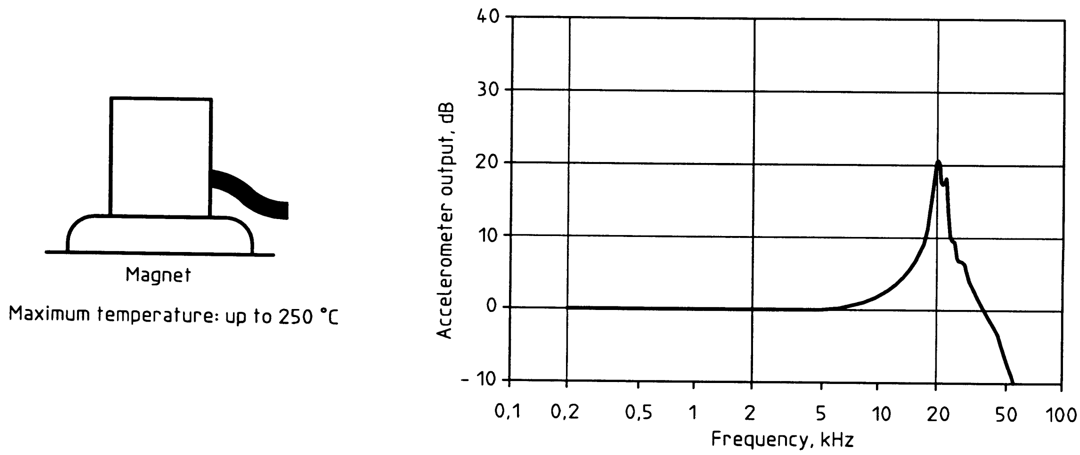
Response influenced by: constancy of measurement direction
constancy of pressure
sufficient pressure
contact area
orientation



NOTE Restricted in use, see **5.4.5**.

Figure 8 — Typical frequency response of a representative hand-held probe relative to the absolute acceleration of the structure at the contact point

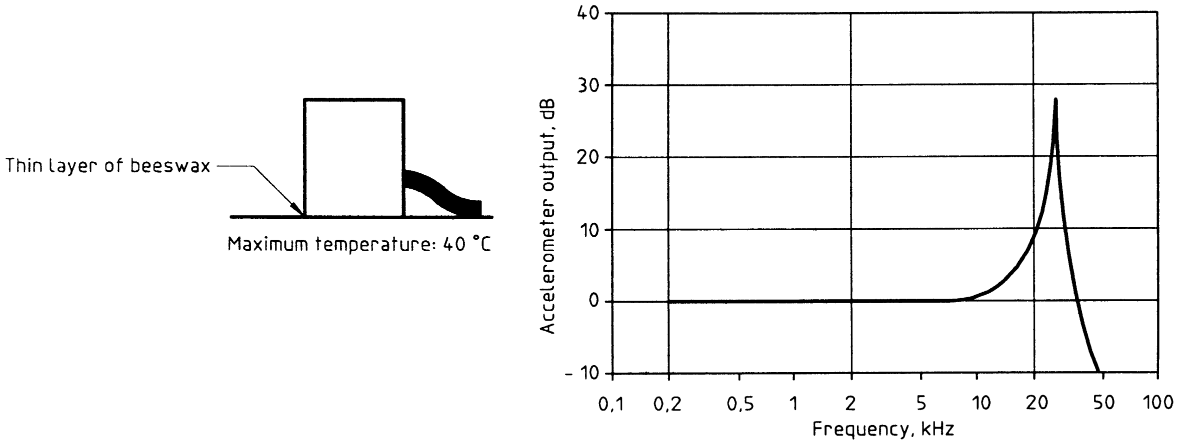
Response influenced by: direction of mounting
flatness of base and surface
mass and thickness of magnet
magnetic properties of material



NOTE Restricted in use, see **5.4.5**.

Figure 9 — Typical frequency response of a representative magnetically mounted accelerometer relative to the absolute acceleration of the structure at its attachment

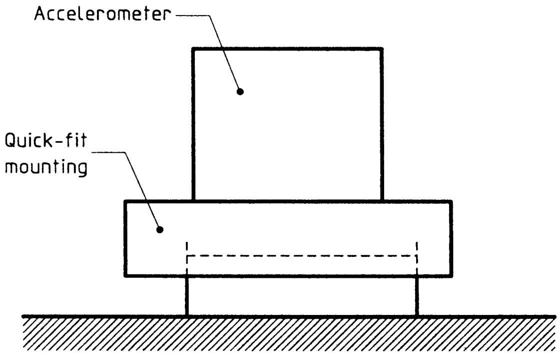
Response influenced by: thickness of wax layer (in relation to mounting area)
temperature
area of pick-up
complex elastic modulii of wax



NOTE Restricted in use, see **5.4.5**.

Figure 10 — Typical frequency response of a representative accelerometer mounted with a thin layer of beeswax relative to the absolute acceleration of the structure at its attachment

Response influenced by: fitting of mounting stud
mounting torque
size of the mounting in relation to the accelerometer
quality of mounting surfaces
mechanical fixing force



NOTE The resonance frequency and amplitude limit of the quick-fit mounting and its accelerometer should be investigated experimentally to determine the upper frequency limit and maximum amplitude that can be measured before distortion of the signal occurs. For this reason no frequency response graph is shown.

Figure 11 — Quick mount

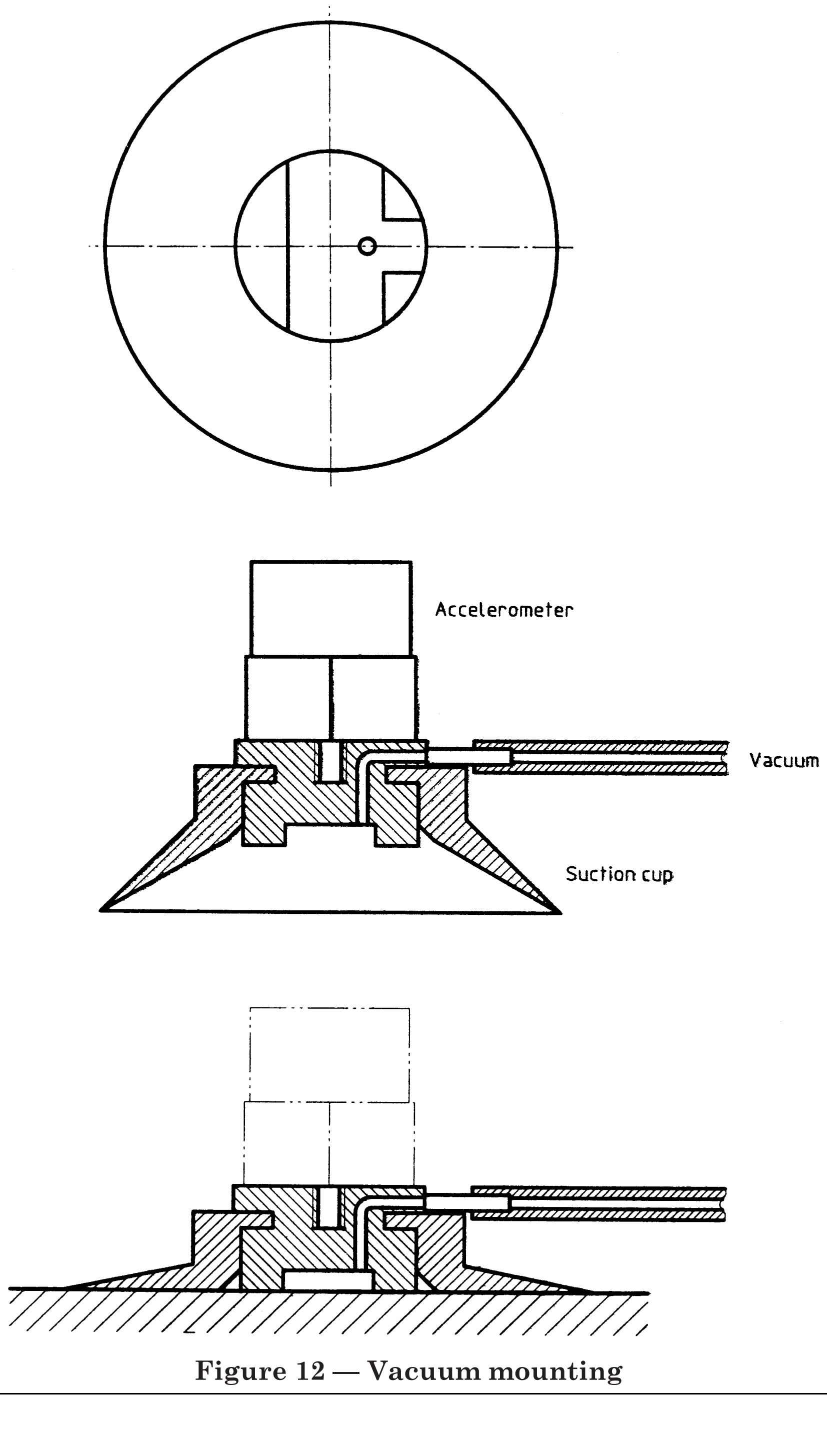


Figure 12 — Vacuum mounting

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