BRITISH STANDARD

BS 6472:1992

Guide to

Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the General Mechanical Engineering Standards Policy Committee (GME/-) to Technical Committee GME/21, upon which the following bodies were represented:

Department of Trade and Industry (National Engineering Laboratory)
Electricity Supply Industry in England and Wales
Engineering Equipment and Materials Users' Association
Institute of Sound and Vibration Research
Institution of Mechanical Engineers
Lloyds Register of Shipping
Ministry of Defence
Power Generation Contractors' Association (BEAMA Ltd.)
Society of British Aerospace Companies Ltd.
Society of Environmental Engineers
Society of Motor Manufacturers and Traders Ltd.

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

British Aggregate Construction Materials Industries
British Agricultural & Garden Machinery Association Ltd.
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Health and Safety Executive
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Contents

Foreword

This British Standard has been prepared under the direction of the Mechanical Engineering Standards Policy Committee. It is a revision of BS 6472:1984 which is withdrawn.

International Standard ISO 2631-2 on this subject contains insufficient information to allow proper evaluation of human response to vibration in buildings and, therefore, this British Standard, which conforms in substantial measure with the international agreement and which contains significant additional guidance, has been updated to take account of recent developments on the subject.

A bibliography of supporting data published elsewhere is included in Appendix D of this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 16, an inside back cover 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.

0 Introduction

Structural vibration in buildings can be detected by the occupants and can affect them in many ways: their quality of life can be reduced as also can their working efficiency. This standard provides guidance on human response to building vibration. Weighting curves related to human response to vibration of buildings are provided.

Complaint levels from occupants of buildings subject to vibration and the acceptable magnitudes, or limits, for building vibration depend upon specific circumstances. Appendix A provides best available information on the application of the weighting curves to different situations. Consideration is given to the time of day and use made of occupied space in buildings; whether workshop, office, residential or a critical area. Tentative guidance is given on the magnitudes of vibration at which adverse comment may begin to arise. In cases where sensitive equipment or delicate tasks impose more stringent criteria than human comfort or annoyance, the corresponding more stringent values should be applied.

1 Scope

This British Standard provides general guidance on human exposure to building vibration in the frequency range 1 Hz to 80 Hz. Curves of equal annoyance for humans are included together with measurement methods to be employed.

Appendix A provides the best available information on the application of the weighting curves to different situations.

Appendix B provides guidance on vibration conditions which may cause adverse comment. Current methods of assessing continuous, intermittent and impulsive vibration are also presented in Appendix B. Blast induced vibration is addressed in Appendix C.

This British Standard does not provide guidance on the probability of structural damage to buildings or injury to occupants of buildings subject to vibration.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Characteristics of building vibration

2.1 Direction of vibration

Because a building may be used for many activities, standing, sitting and lying may all occur. For example, vertical vibration of the building may enter the body as either x-axis, y-axis or z-axis vibration, as defined in Figure 1.

This standard distinguishes between these three axes of vibration, and normally the measured vibration should be referred to the appropriate axis.

2.2 Frequency weighting

There is evidence from research concerning the building environment to suggest that there are summation effects for vibration at different frequencies. Therefore, for the evaluation of building vibration with respect to annoyance and comfort, overall weighted values of the vibration are preferred.

2.3 Time history of vibration

Building vibrations as they affect people may be classified as impulsive or continuous as follows.

a) Impulsive vibration is a rapid build-up to a peak followed by a damped decay which may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, i.e. less than 2 s.

b) Continuous vibration is vibration which continues uninterrupted for either a day time period of 16 h or a night time period of 8 h, for example 23.00 h to 07.00 h.

In addition vibration may be intermittent. A procedure is described in Appendix B to relate the severity of intermittent vibration to that for continuous vibration.

3 Measurement of vibration

3.1 Introduction to the use of acceleration or particle velocity

In general, building vibration should be measured in acceleration terms. In some cases, such as impulsive events, it may be found convenient to measure in terms of particle velocity so that peak values may be identified.

A suitable technique is to record unfiltered time histories from which any desired value can later be determined, although it is acceptable to carry out field evaluation with appropriate instrumentation.

Performance characteristics for appropriate instrumentation for measuring acceleration can be obtained in BS 6841 and BS 7482-1 and BS 7482-3.

Guidance on general performance characteristics for current instrumentation to measure peak particle velocity is given in Appendix C.

3.2 Location for measurements

Measurements of vibration should normally be taken on a building structural surface supporting a human body. In some circumstances, measurements may have to be made outside the structure, or on some surface other than points of entry to the human subject. Where measurements are made other than at the point of entry of vibration to the body an allowance should be made for the transfer function between the measurement point and the point of entry to the body. It is essential that this allowance is specified by the investigator.

Preferably, measurements should be taken along the three orthogonal axes shown in Figure 1, and reference made to the appropriate curves of Figure 2 to Figure 7 for each axis of the human body.

If the orientation of the occupants with respect to the vibration environment is constant and known, the weighting functions established for the x, y, or z directions should be used. If the orientation of the occupants is varying or unknown with respect to the detected vibration, the weighted values should normally be obtained for all axes and the highest value used.

3.3 Information on evaluation criteria and procedures currently in use

Information on evaluation criteria and procedures currently in use are shown in Appendix A.

Current information on multiplying factors to be used with base curves to specify satisfactory magnitudes of building vibration to keep human response (annoyance, complaints) to acceptable levels are presented in Appendix A (see Table 5). The corresponding r.m.s. acceleration and particle peak velocity curves are given in Figure 4 to Figure 7.

NOTE It is recognized that the relation between r.m.s. acceleration and peak velocity depends upon the nature of the waveform. The curves for peak velocity are calculated assuming sinusoidal motion. The relationship between the weighted acceleration and the peak particle velocity is shown in Table 8.

3.4 Guidance on appropriate usage of acceleration assessment (with reference to Appendix A)

Vibration should be assessed on the basis of the vibration dose value (VDV) or the r.m.s. value of the frequency-weighted acceleration. Appendix B defines the appropriate procedures.

3.5 Guidance on appropriate usage of peak particle velocity assessment (with reference to Appendix A and Appendix C)

Where peak particle velocity records have been obtained for impulsive events, then the records can be treated as described in Appendix C for comparison with the guidance magnitudes given in Appendix A.

Continuous vibration records in terms of velocity can be assessed using the guidance contained in Appendix A.

Table 1 — Acceleration values for the base curve in Figure 2

Frequency	Acceleration (r.m.s.)
Hz	m/s^2
1	1.00×10^{-2}
1.25	8.94×10^{-3}
1.60	7.91×10^{-3}
2.00	7.07×10^{-3}
2.50	6.32×10^{-3}
3.15	5.63×10^{-3}
4.00	5.00×10^{-3}
5.00	5.00×10^{-3}
6.30	5.00×10^{-3}
8.00	5.00×10^{-3}
10.00	6.25×10^{-3}
12.50	7.81×10^{-3}
16.00	1.00×10^{-2}
20.00	1.25×10^{-2}
25.00	1.56×10^{-2}
31.50	1.97×10^{-2}
40.00	2.50×10^{-2}
50.00	3.13×10^{-2}
63.00	3.94×10^{-2}
80.00	5.00×10^{-2}

Table 2 — Acceleration values for the base curve in Figure 3

Frequency	Acceleration (r.m.s.)
Hz	m/s^2
1	3.57×10^{-3}
1.25	3.57×10^{-3}
1.60	3.57×10^{-3}
2.00	3.57×10^{-3}
2.50	4.46×10^{-3}
3.15	5.63×10^{-3}
4.00	7.14×10^{-3}
5.00	8.93×10^{-3}
6.30	1.13×10^{-2}
8.00	1.43×10^{-2}
10.00	1.79×10^{-2}
12.50	2.23×10^{-2}
16.00	2.86×10^{-2}
20.00	3.57×10^{-2}
25.00	4.46×10^{-2}
31.50	5.63×10^{-2}
40.00	7.14×10^{-2}
50.00	8.93×10^{-2}
63.00	1.13×10^{-1}
80.00	1.43×10^{-1}

Table 3 — Velocity (peak) values for the base curve (curve 1) in Figure 5

Frequency	Velocity (peak)
Hz	m/s
1	2.25×10^{-3}
1.25	1.61×10^{-3}
1.60	1.11×10^{-3}
2.00	7.96×10^{-4}
2.50	5.69×10^{-4}
3.15	4.02×10^{-4}
4.00	2.81×10^{-4}
5.00	2.25×10^{-4}
6.30	1.79×10^{-4}
8.00	1.41×10^{-4}
10.00	
12.50	
16.00	
20.00	
25.00	
31.50	
40.00	
50.00	
63.00	
80.00	

Table 4 — Velocity (peak) values for the base curve (curve 1) in Figure 7

Frequency	Velocity (peak)
Hz	m/s
1	8.04×10^{-4}
1.25	6.43×10^{-4}
1.60	5.02×10^{-4}
2.00	4.02×10^{-4}
2.50	
3.15	
4.00	
5.00	
6.30	
8.00	
10.00	
12.50	
16.00	
20.00	
25.00	
31.50	
40.00	
50.00	
63.00	
80.00	

4 Characterization of building vibration with respect to human response

4.1 Factors which influence human response

Comments regarding building vibrations in residential situations are likely to arise from occupants of buildings when the vibration levels are only slightly in excess of thresholds of perception. In general, satisfactory magnitudes are related to adverse comments of the occupants and are not determined by any other factors such as short term health hazard or working efficiency.

Situations exist where motion magnitudes above those generally corresponding to minimal adverse comment level can be tolerated, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project. Any startle factor can be reduced by warning signals, announcements and/or regularity of occurrence, and a proper programme of public relations. In cases of long term vibration, adverse comments may be modified by familiarization.

The criteria to be used with respect to human response should be selected on the basis of the expected occupation and the activity of the occupants. Each occupied room of a building should be analysed with respect to these criteria.

4.2 Satisfactory vibration magnitudes in buildings

4.2.1 *General*

The base curves of Figure 2 and Figure 3 represent magnitudes of vibration in buildings for approximately equal human response with respect to human annoyance and/or complaints about interference with activities. Satisfactory vibration magnitudes in buildings should be specified in multiples of the base curve magnitudes or measured magnitudes compared with the r.m.s. acceleration or vibration dose values given in Table 6 or Table 7. At vibration magnitudes below the base curves in Figure 2 to Figure 7 adverse comments or complaints of vibration are rare. However, this statement does not imply that, depending on circumstances and expectations, annoyance and/or complaints are necessarily to be expected at higher magnitudes.

Weighted acceleration values are to be evaluated with respect to the base acceleration magnitudes in the frequency band of maximum sensitivity.

Establishing design criteria and goals by raising the base curves in Figure 2 to Figure 7 should be done by reference to current experiences and by giving proper consideration to social, public relations and economic factors, having minimized the vibration magnitudes as far as is reasonably practicable.

NOTE The base curves presented do not take account of the possibility that at frequencies above approximately 30 Hz, vibration can introduce undesired acoustical disturbances. The curves are those currently used for assessing human response to vibration in buildings and are not necessarily the same shape as vibration perception thresholds.

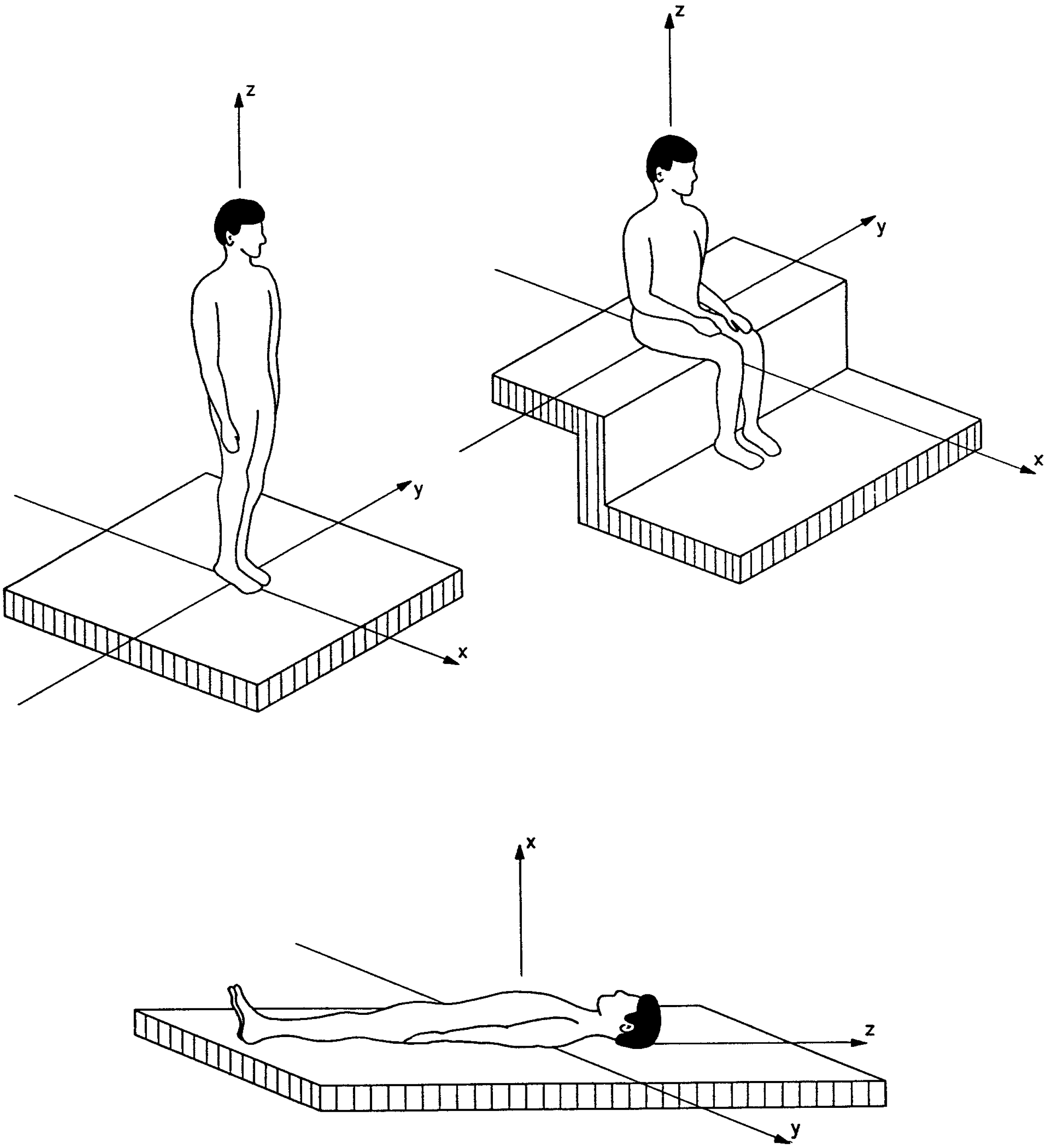
4.2.2 *Base curve for foot-to-head (z-axis) vibration*

For z-axis vibration, the base curve is shown in Figure 2. Table 1 defines the corresponding acceleration values.

4.2.3 *Base curve for back-to-chest or side-to-side (x- or y-axis) vibration*

For x- or y-axis vibration, a different base curve applies. This is shown in Figure 3. Table 2 defines the corresponding acceleration values.

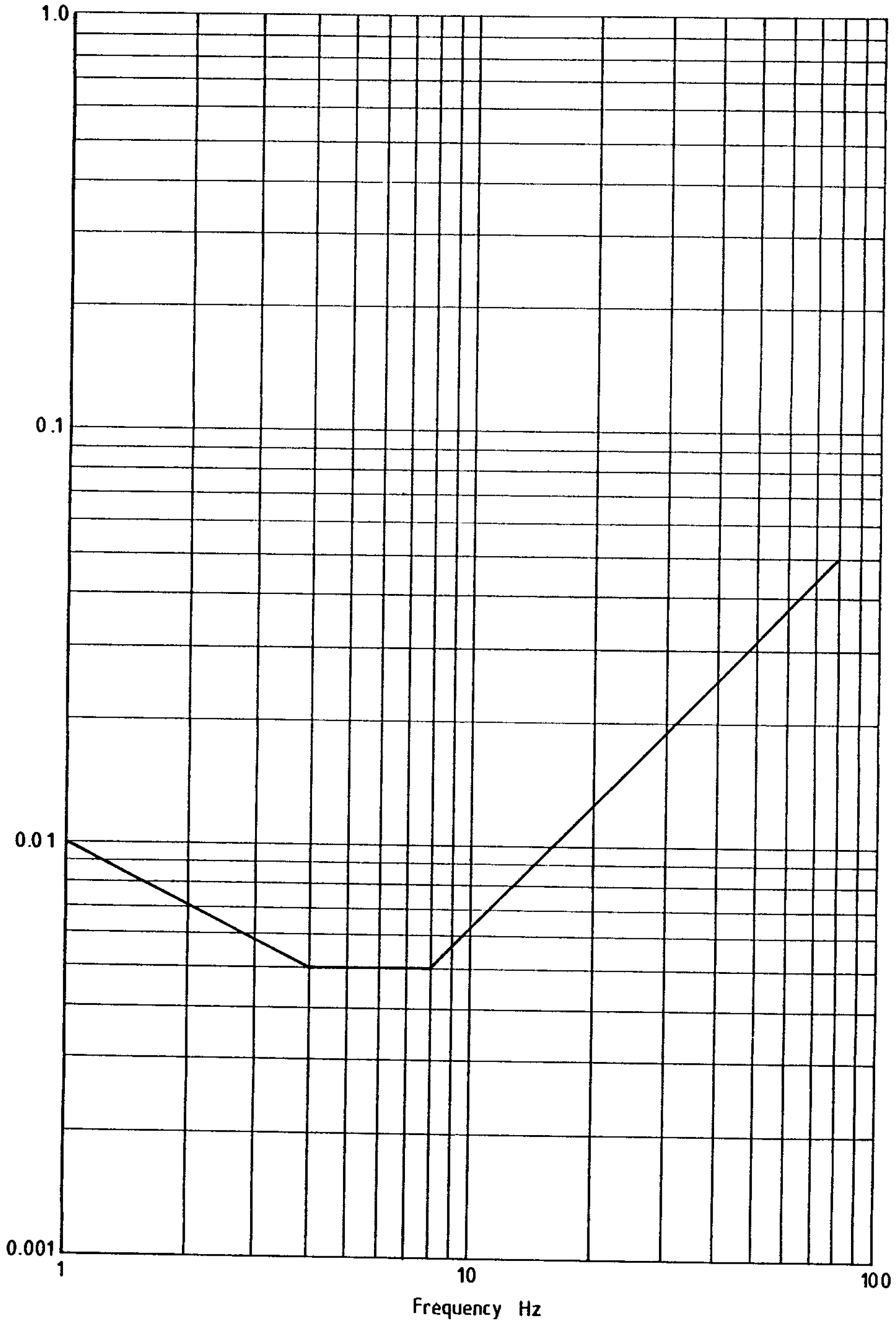
The base curve for x- and y-axis vibration is lower than the z-axis curve at low frequencies. This is due to the sensitivity of the human body to x- or y-axis motion at these low frequencies.



Key

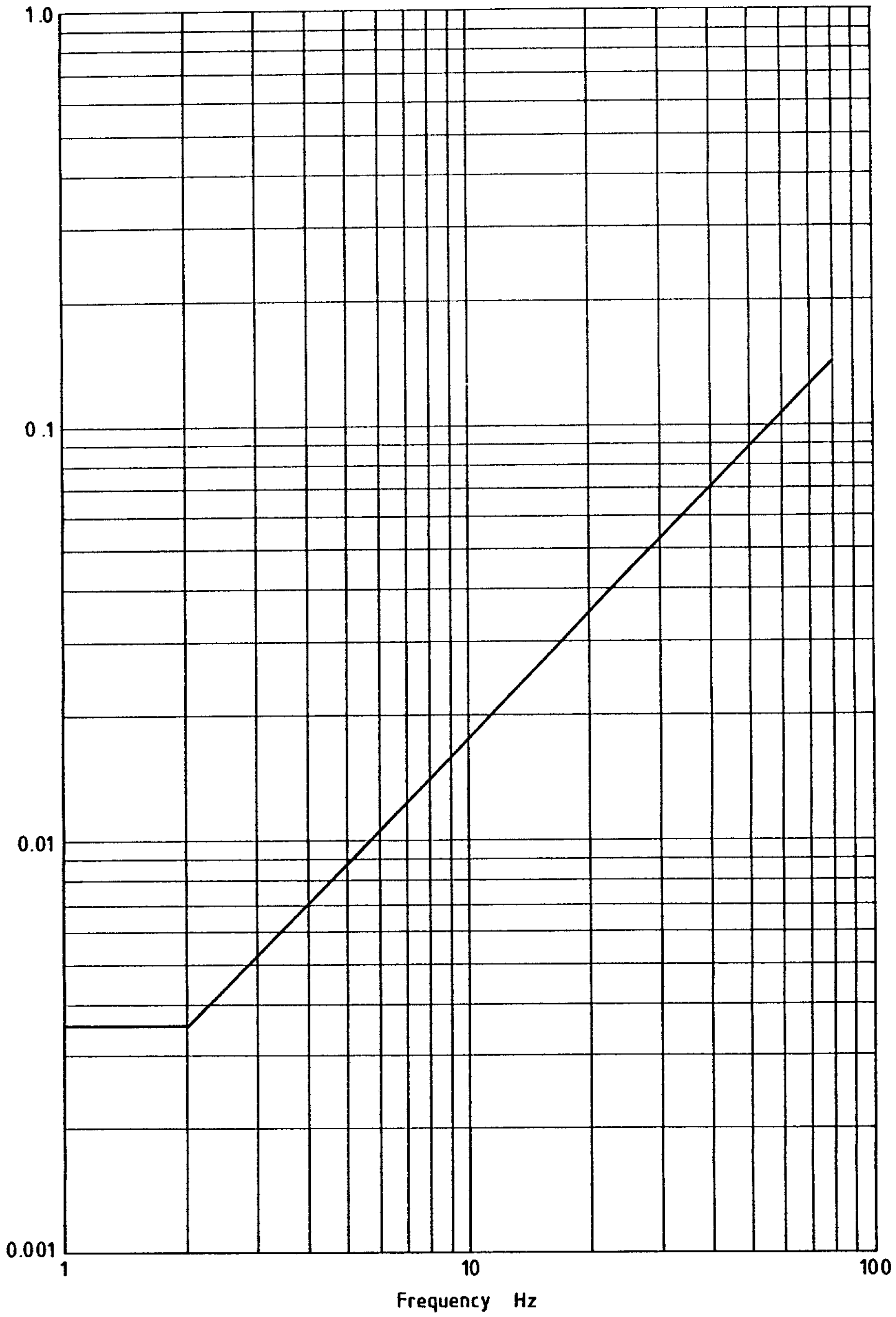
a_x, a_y, a_z = acceleration in the directions of x, y, z axes
x-axis = back to chest
y-axis = right side to left side
z-axis = foot to head

Figure 1 — Directions of basicentric coordinate systems for mechanical vibration influencing humans



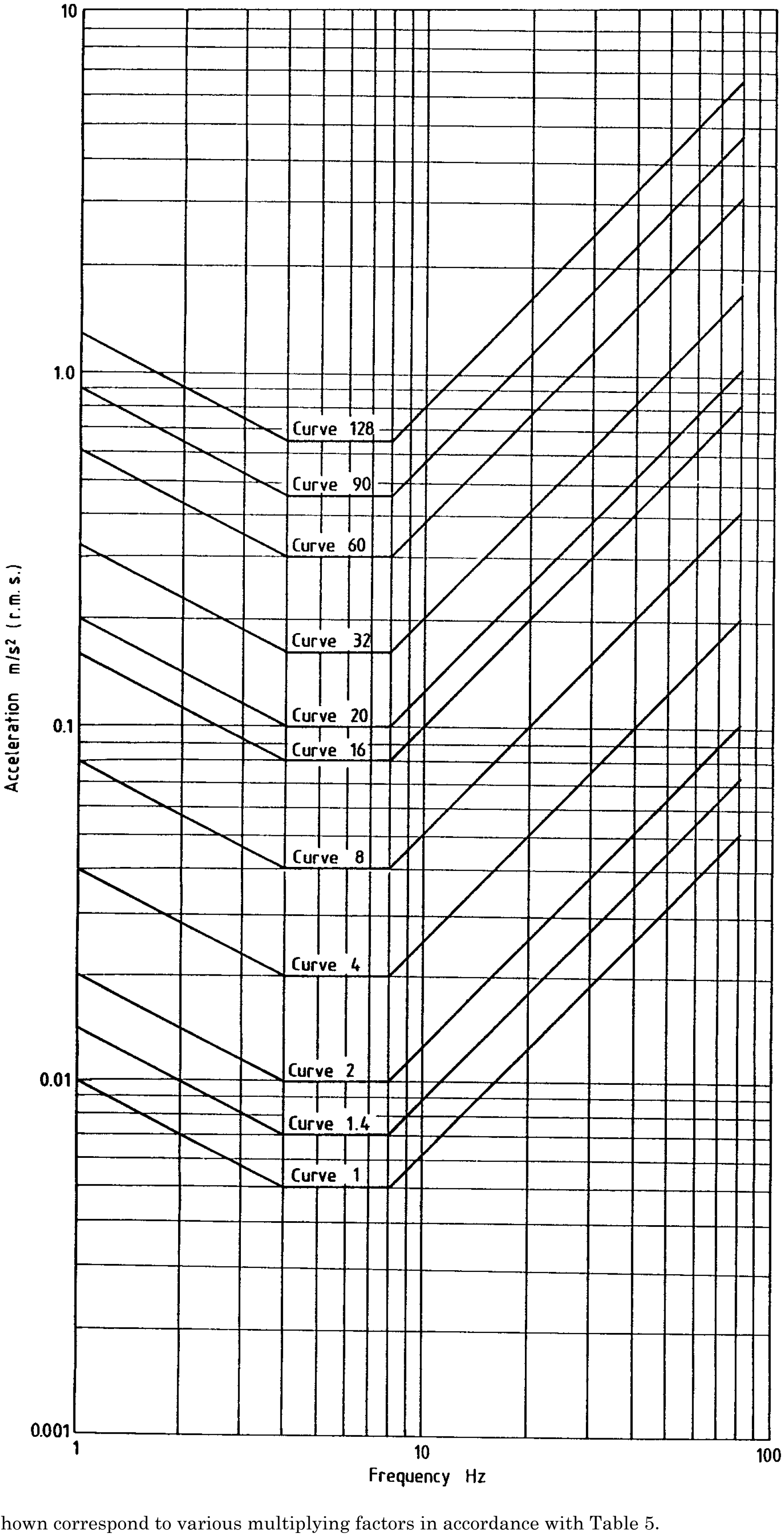
NOTE See **4.2.1**, **4.2.2** and Table 1.

Figure 2 — Building vibration z-axis base curve for acceleration (r.m.s.)



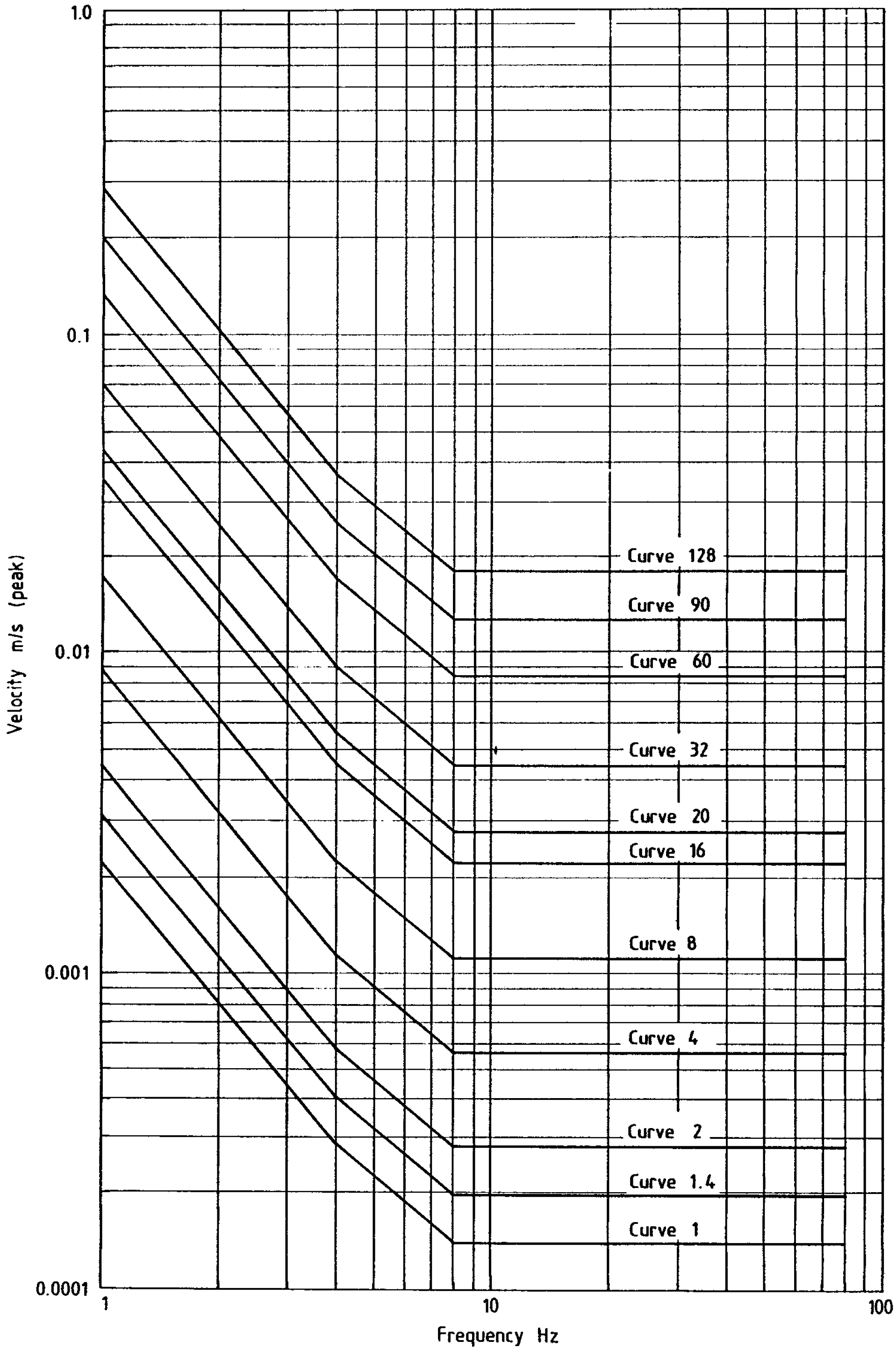
NOTE See **4.2.3** and Table 2.

Figure 3 — Building vibration x-axis and y-axis base curve for acceleration (r.m.s.)



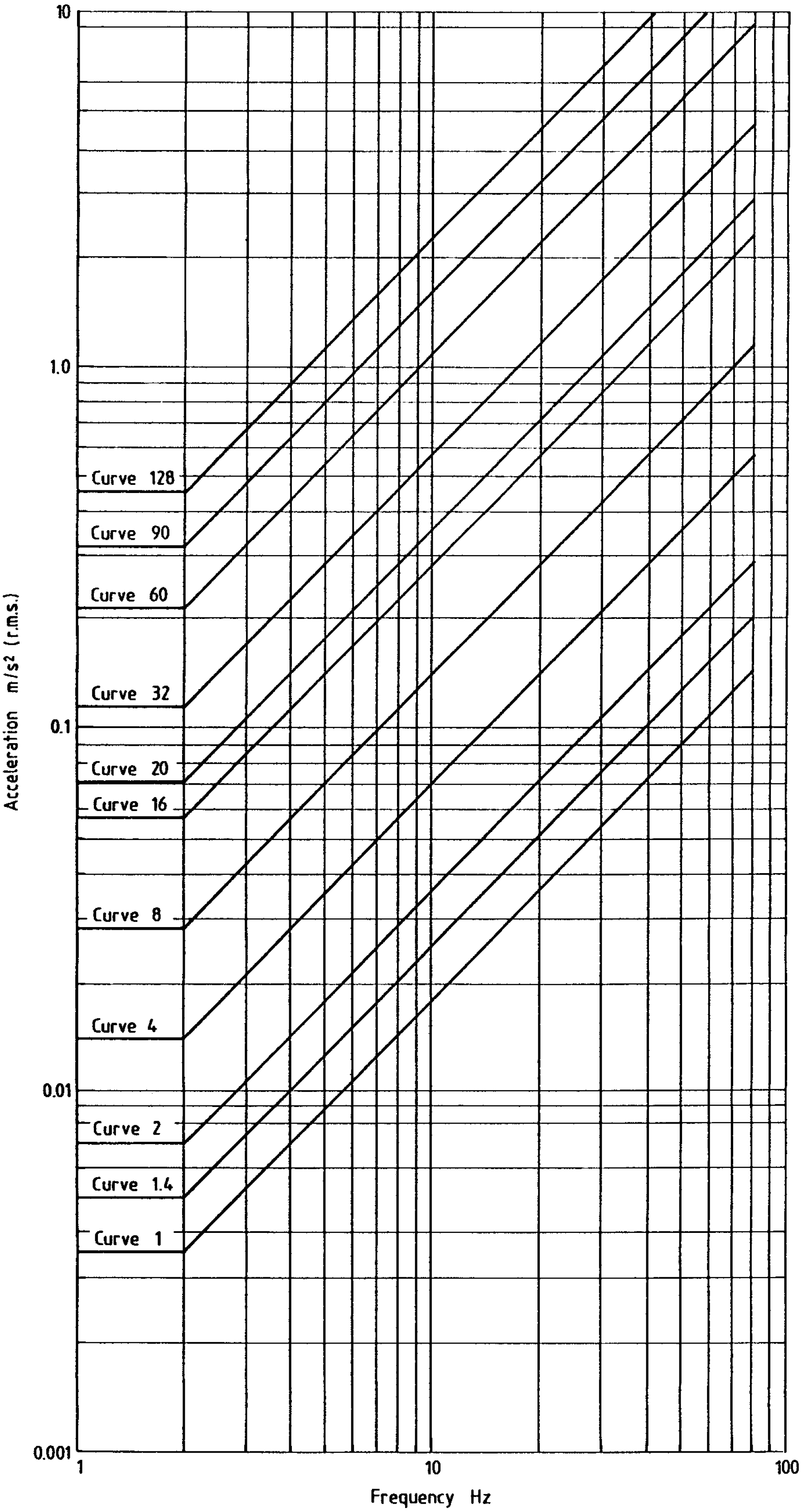
NOTE The curves shown correspond to various multiplying factors in accordance with Table 5.

Figure 4 — Building vibration z-axis curves for acceleration (r.m.s.)



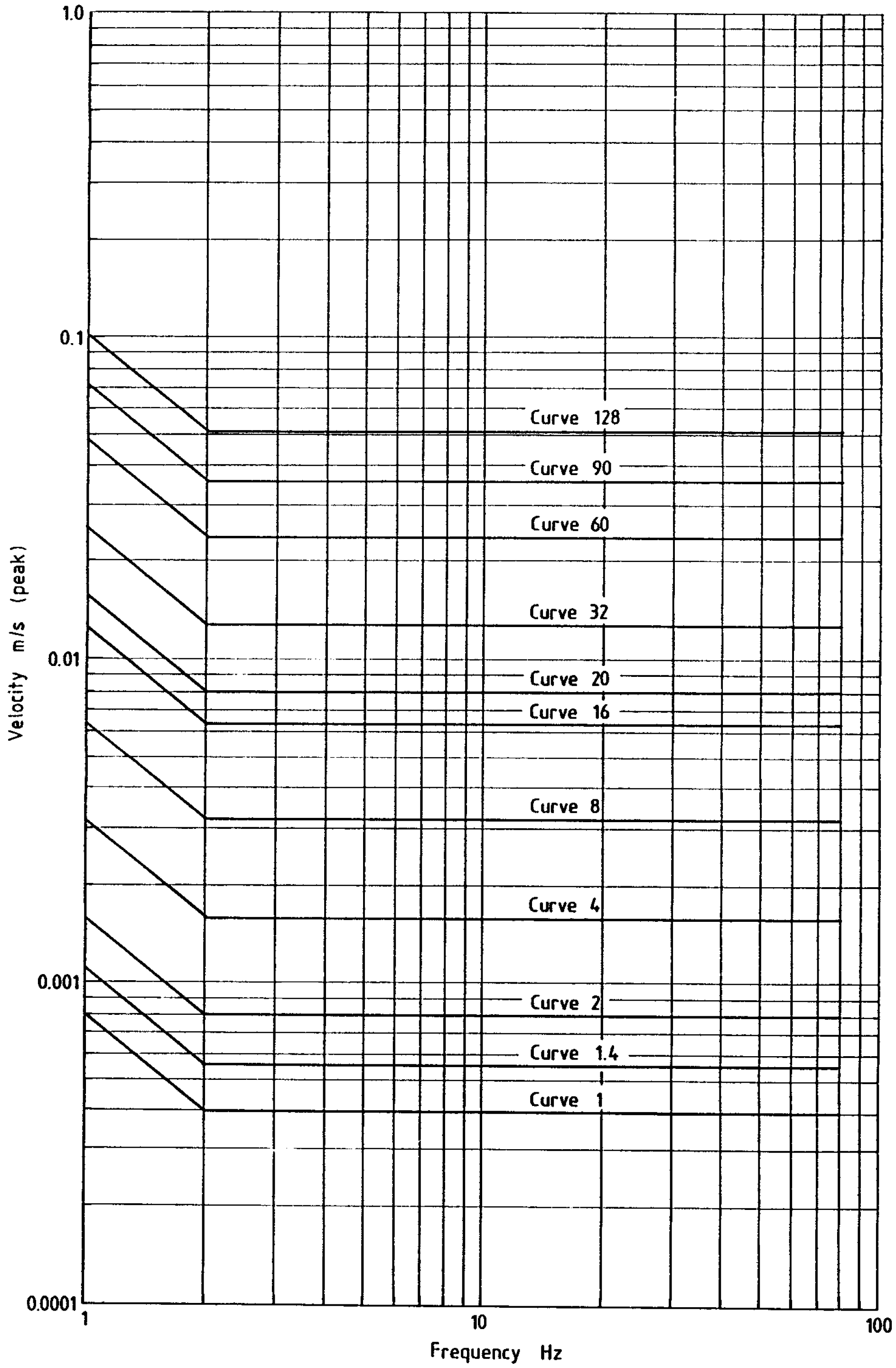
NOTE The curves shown correspond to various multiplying factors in accordance with Table 5. See Table 3 for numerical values for the base curve.

Figure 5 — Building vibration z-axis curves for peak velocity



NOTE The curves shown correspond to various multiplying factors in accordance with Table 5.

Figure 6 — Building vibration x- and y-axis curves for acceleration (r.m.s.)



NOTE The curves shown correspond to various multiplying factors in accordance with Table 5. See Table 4 for numerical values for the base curve.

Figure 7 — Building vibration x- and y-axis curves for peak velocity

Appendix A Information on evaluation criteria and procedures currently in use

Table 5 — Multiplying factors used to specify satisfactory magnitudes of building vibration with respect to human response

Place	Time	Multiplying factors (see notes 1 and 5)	
		Exposure to continuous vibration [16 h day, 8 h night] (see note 2 and Appendix B)	**Impulsive vibration excitation with up to 3 occurrences** (see note 8)
Critical working areas (e.g. hospital operating theatres, precision laboratories (see notes 3 and 10)	Day	1	1
	Night	1	1
Residential	Day	2 to 4 (see note 4)	60 to 90 (see notes 4 and 9, and Appendix B)
	Night	1.4	20
Office	Day	4	128 (see note 6)
	Night	4	128
Workshops	Day	8 (see note 7)	128 (see notes 6 and 7)
	Night	8	128

NOTE 1 Table 5 leads to magnitudes of vibration below which the probability of adverse comments is low (any acoustical noise caused by structural vibration is not considered).

NOTE 2 Doubling of the suggested vibration magnitudes may result in adverse comment and this may increase significantly if the magnitudes are quadrupled (where available, dose/response curves may be consulted).

NOTE 3 Magnitudes of vibration in hospital operating theatres and critical working places pertain to periods of time when operations are in progress or critical work is being performed. At other times magnitudes as high as those for residences are satisfactory provided there is due agreement and warning.

NOTE 4 Within residential areas people exhibit wide variations of vibration tolerance. Specific values are dependent upon social and cultural factors, psychological attitudes and expected degree of intrusion.

NOTE 5 Vibration is to be measured at the point of entry to the entry to the subject. Where this is not possible then it is essential that transfer functions be evaluated.

NOTE 6 The magnitudes for vibration in offices and workshop areas should not be increased without considering the possibility of significant disruption of working activity.

NOTE 7 Vibration acting on operators of certain processes such as drop forges or crushers, which vibrate working places, may be in a separate category from the workshop areas considered in Table 3. The vibration magnitudes specified in relevant standards would then apply to the operators of the exciting processes.

NOTE 8 Appendix C contains guidance on assessment of human response to vibration induced by blasting.

NOTE 9 When short term works such as piling, demolition and construction give rise to impulsive vibrations it should be borne in mind that undue restriction on vibration levels can significantly prolong these operations and result in greater annoyance. In certain circumstances higher magnitudes can be used.

NOTE 10 In cases where sensitive equipment or delicate tasks impose more stringent criteria than human comfort, the corresponding more stringent values should be applied. Stipulation of such criteria is outside the scope of this standard.

A.1 General

The multiplying factors for continuous day time vibration, given in column 3 of Table 5, apply to a 16 h exposure period. The estimated vibration dose value corresponding to a unity multiplying factor is then approximately 0.1 m/s$^{1.75}$, i.e.

$$\begin{aligned}\text{eVDV} &= 1.4 \times a(\text{r.m.s.}) \times t^{0.25}\\ &= 1.4 \times 0.005 \times [16 \times 60 \times 60]^{0.25}.\end{aligned}$$

NOTE See Appendix B for calculation of vibration dose values.

The multiplying factors for night time apply to an 8 h exposure period. The estimated vibration dose value corresponding to a unity multiplying factor is then approximately 0.091 m/s$^{1.75}$, i.e.

$$\begin{aligned}\text{eVDV} &= 1.4 \times a(\text{r.m.s.}) \times t^{0.25}\\ &= 1.4 \times 0.005 \times [8 \times 60 \times 60]^{0.25}.\end{aligned}$$

The r.m.s. acceleration corresponding to the vibration dose values varies according to the duration of exposure. Table 6 shows how the r.m.s. acceleration corresponding to a low probability of adverse comments during the daytime (i.e. multiplying factors of 2 to 4 in Table 5) varying with exposure duration.

Table 6 — Frequency weighted r.m.s. acceleration (m/s^2 r.m.s.) corresponding to a low probability of adverse comment

Place	Exposure periods				
	16 h	1 h	225 s	14 s	0.9 s
Residential buildings day time	0.01 to 0.02	0.02 to 0.04	0.04 to 0.08	0.08 to 0.16	0.16 to 0.32

A.2 Worked examples

Example 1.A

Ten occurrences, each of 25 s, with a frequency-weighted r.m.s. acceleration of 0.1 m/s^2 r.m.s., during a 16 h day. The estimated vibration dose (eVDV) is calculated as follows:

$$\begin{aligned} \text{eVDV} &= 1.4 \times a \text{ (r.m.s.)} \times t^{0.25} \\ &= 1.4 \times 0.1 \times (10 \times 25)^{0.25} \\ &= 0.557 \text{ m/s}^{1.75} \end{aligned}$$

Referring to Table 7, it will be concluded that adverse comments are possible.

Table 7 — Vibration dose values (m/s$^{1.75}$) above which various degrees of adverse comment may be expected in residential buildings

Place	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Residential buildings 16 h day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8 h night	0.13	0.26	0.51

Example 2.A

A residence is situated next to a railway line along which 81 trains pass in a 16 h day. The passage of each train lasts 16 s, over which period the r.m.s. frequency-weighted acceleration is $a_{\text{r.m.s.}}$

eVDV for each train = $1.4 \times a_{\text{r.m.s.}} \times t^{0.25} = 1.4 \times a_{\text{r.m.s.}} \times 16^{0.25} = 2.8 \times a_{\text{r.m.s.}}$

eVDV over one day = $1.4 \times a_{\text{r.m.s.}} \times t^{0.25} = 2.8 \times a_{\text{r.m.s.}} \times 81^{0.25} = 8.4 \times a_{\text{r.m.s.}}$

If eVDV = 0.2, $a_{\text{r.m.s.}} = 0.2/8.4 = 0.024$ m/s^2 r.m.s., etc.

So, referring to Table 7:

Low probability of adverse comment

if $a_{\text{r.m.s.}} = 0.024$ m/s^2 to 0.048 m/s^2 r.m.s.

Adverse comment possible

if $a_{\text{r.m.s.}} = 0.048$ m/s^2 to 0.096 m/s^2 r.m.s.

Adverse comment probable

if $a_{\text{r.m.s.}} = 0.096$ m/s^2 to 0.192 m/s^2 r.m.s.

Appendix B Vibration dose values

B.1 General

Vibration dose values may be used to assess the severity of impulsive and intermittent vibration (see BS 6841). The vibration dose value time-dependency means a two-fold decrease in vibration magnitude is equivalent to a 16-fold decrease in the duration of the vibration. (It is a "fourth power" time dependency: a^4t = constant, where a is the r.m.s. frequency-weighted acceleration and t is the duration of exposure.)

Where possible, the vibration dose value (VDV) should be determined from a measurement obtained over the full exposure to vibration. The vibration dose value is given by the fourth root of the integral of the fourth power of the acceleration after it has been frequency-weighted:

$$\text{VDV} = \left(\int_0^T a^4(t)\,\mathrm{d}t\right)^{0.25}$$

where

VDV is the vibration dose value (in m/s$^{1.75}$);

$a(t)$ is the frequency-weighted acceleration;

T is the total period of the day (in s) during which vibration may occur.

B.2 Estimation of vibration dose values

The total vibration dose value for the day is approximately given by:

$$\text{eVDV} = 1.4 \times a\text{(r.m.s.)} \times t^{0.25}$$

where

eVDV is the estimated vibration dose value (in m/s$^{1.75}$);

a(r.m.s.) is the r.m.s. value (in m/s^2);

t is the total duration of vibration exposure (in s).

NOTE 1 This procedure will underestimate the true vibration dose value when the crest factor exceeds about 6. The error will tend to increase with increases in the crest factor.

NOTE 2 The correction factor 1.4 has been determined empirically from typical vibration environments having low crest factors. Where there is any doubt or difference between true vibration dose values and estimated dose values, the vibration dose values should be calculated directly.

B.3 Repeated exposures

Where the vibration conditions are constant (or regularly repeated) throughout the day, only one representative period, in seconds, (of duration t_1) need be measured. If the measured vibration dose value is VDV_1, the total vibration dose value for the day, (VDV_d) will then be given by the following equation.

$$\mathrm{VDV}_\mathrm{d} = (t_\mathrm{d}/t_1)^{0.25} \times \mathrm{VDV}_1$$

where

t_d is the duration of exposure per day (s).

If, in a day, there is a total of N periods of various durations with vibration dose value, VDV_n, the total vibration dose value for the day is given by:

$$\mathrm{VDV} = \left(\sum_{n=1}^{n=N} \mathrm{VDV}_n{}^4 \right)^{0.25}$$

Appendix C Guide to the evaluation of vibration induced by blasting

C.1 General

This appendix contains information for assessment of human exposure to blast induced vibration in buildings.

C.2 Vibration measurement

For blasting it is the current practice to measure the peak value of the velocity using velocity transducers. Currently used equipment is typically capable of measurement over the range 0.0001 m/s (0.1 mm/s) to 0.1 m/s (100 mm/s) with an accuracy within 5 % and with a frequency response flat to within 5 % over the frequency range of 4.5 Hz to 250 Hz. Results obtained may differ slightly between sets of equipment. Reference should be made to the published standards on vibration measuring instrumentation (see the list of publications referred to).

In some cases it may be preferable to measure in terms of acceleration either as an alternative to velocity or in addition.

Specific site circumstances will dictate optimum ranges and parameters.

In the case of blasting it is often impractical to measure inside occupied buildings. In such cases measurements should be taken outside of the buildings and preferably on a hard surface as close to the property as possible. Alternatively, transducers may be buried if no such surface is available. Where measurements are made other than at the point of entry of vibration to the body it is essential that an allowance should be made for the transfer function between the measurement point and the point of entry to the body. It is essential that this allowance is specified by the investigator.

In the absence of information to the contrary, it is reasonable to assume that in a residential building a person is downstairs and either sitting or standing during the day time and at night time is upstairs and lying down. However, because of the varied use of some buildings, it may not be possible to correlate the x, y and z axes as discussed within this standard with the measured transverse, longitudinal and vertical axes. Consequently, the lower numerical value of structural vibration, obtained from Appendix A, is the one to be adopted.

C.3 Factors which influence human response

It is particularly the case with blast induced vibration that vibration levels only slightly in excess of perception level can give rise to complaints. Thus the factors detailed in **4.1** are especially relevant.

The following are of particular importance:

a) the regular timing of blasts;

b) audible warning signals;

c) a proper programme of public relations.

Any public relations programme should recognize the fact that it is often the fear of building damage that leads to concern being expressed. It should also recognize the value, where appropriate, of blasting trials to establish a blasting schedule, followed by regular vibration monitoring in order to demonstrate compliance with appropriate vibration limits.

In general the human response recommendations made within this appendix are relative to long term blasting operations such as from surface mineral extraction sites. For civil engineering projects, such as tunnels and foundation excavations, it should be recognized that the application of human response criteria, rather than conservative damage criteria, could significantly prolong project durations, which in turn could significantly increase costings with no benefit in terms of reduced complaint likelihood.

C.4 Satisfactory vibration magnitudes

In the case of blast induced vibration it is well recognized that data scatter will be present. It is recommended that satisfactory vibration magnitudes should not be exceeded by more than 10 % of the blasts. No blast should give rise to vibration which exceeds the satisfactory magnitude by more than 50 %. Due consideration should be given to the time period and the number of blasts.

Table 5, column 4, details the multiplying factors used to specify satisfactory magnitudes. For blast vibration for up to three blasts per day the generally accepted multiplying factor for day time residential blasting is curve 60. Normally night time blasting is not permitted but in circumstances where night time blasting is carried out then the appropriate multiplying factor is curve 20.

For a given vibration magnitude an individual's tolerance to perceived vibration will decrease as the number of events increases.

When more than three blasting events occur in a 16 h day the relationship below has been found to be most useful in maintaining equivalent human response. This relationship is used to derive the additional multiplying factor F, which should be applied to the "residential multiplying factor" in column 4 of Table 5, to further reduce satisfactory magnitudes.

$$F = 1.7\ N^{-0.5} T^{-d}$$

where

N is the number of events in a 16 h day (and $N > 3$);

T is the duration of the events in s;

d is zero for T less than 1 s;

For T greater than 1 s, $d = 0.32$ for wooden floors;
$d = 1.22$ for concrete floors.

A blasting event is defined as a vibration exceeding 0.5×10^{-3} m/s velocity (peak) or background vibration level, whichever is the greatest. Duration is defined as the period of time, in s, that this level is exceeded.

This relationship does not apply when values lower than those given by the factors for continuous vibration in Table 5 result.

C.5 Examples

In practice vertical axis vibration will normally govern in respect to human response.

Example 1.C

An open pit site requires blasting for overburden removal, with no more than three blasts per day being necessary. This site is adjacent to a residential area.

Table 5 details the relevant multiplying factors used to specify satisfactory magnitudes of building vibration with respect to human response. In this case we are concerned with residential buildings during day time and, therefore, curves 60 to 90 are relevant. Normally curve 60 would be used for the assessment of human response to blast induced vibration of buildings.

To interpret this factor in terms of an actual vibration magnitude, Figure 4 to Figure 7 can be consulted. Figure 4 and Figure 6 will interpret the multiplying factors in terms of r.m.s. acceleration, and Figure 5 and Figure 7 in terms of peak particle velocity.

The operators of this site, in line with the majority of explosive users, work to vibration magnitudes in terms of velocity and therefore Figure 5 and Figure 7 can be used.

Figure 5 shows that curve 60 represents 0.0085 m/s or 8.5 mm/s peak particle velocity for all frequencies at 8 Hz or above for z-axis vibration (see Figure 1 for axes definitions).

(To interpret any multiplying factor for the z-axis at 8 Hz or above without reference to Figure 5, simply multiply the factor by 0.141, i.e. curve 60 represents 60 × 0.141 which is approximately equal to 8.5 mm/s (see also Table 8).

Predominant frequencies are known to be well above 8 Hz and thus the site magnitude suggested by this guide is that for the vertical axis which governs:

satisfactory z-axis vibration magnitude 8.5 mm/s (or 8.5×10^{-3} m/s).

In practice, the pit operators made the reasonable assumption that in the day time their neighbouring residents would be either sitting or standing in the downstairs part of their property. They therefore designed all blasts such that their vertical component, measured in accordance with **C.2**, was less than 8.5 mm/s for at least 90 % of all blasts.

Table 8 — Relationship between the curve number, the weighted acceleration (m/s^2 r.m.s.) and the peak particle velocity (mm/s) for z-axis vibration

Curve No.	Frequency weighted		
	Acceleration r.m.s.	Peak particle velocity	Ratio
	m/s^2	mm/s	
1	0.005	0.141	28.2
1.4	0.007	0.197	28.2
2	0.010	0.282	28.2
4	0.020	0.564	28.2
8	0.040	1.128	28.2
16	0.080	2.256	28.2
20	0.100	2.820	28.2
32	0.160	4.512	28.2
60	0.300	8.460	28.2
90	0.450	12.69	28.2
128	0.640	18.05	28.2

Example 2.C

The same site as above now wishes to blast six times per day.

The normal multiplying factor of 60 is still applicable, but now, since more than three events per day are envisaged, an *F* factor needs to be determined to further reduce the satisfactory magnitude.

It is stated in **C.4** that the chosen multiplying factor of 60 should be further multiplied by factor *F*.

In this case the number of events, *N*, is 6 and inspection of the vibration traces taken at the concrete floor concerned shows that vibration durations are 1.3 s, with predominant frequencies above 8 Hz.

$$\begin{aligned} \text{Thus } F &= 1.7 \times N^{-0.5} \times T^{-d} \\ &= 1.7 \times 6^{-0.5} \times 1.3^{-1.22} \\ &= 1.7 \times 0.408 \times 0.726 \\ &= 0.50 \end{aligned}$$

The multiplying factor of 60 therefore becomes 60 × 0.50 = 30, so the suggested site satisfactory governing z-axis vibration magnitude is

$$30 \times 0.141 = 4.2 \text{ mm/s}$$

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