Guide to

Measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock

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Co-operating organizations

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

British Engine Group of SMMT
British Maritime Technology
British Steel Corporation
Department of Trade and Industry (National Engineering Laboratory)
Electricity Supply Industry in England and Wales
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Institution of Electronic and Radio Engineers
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Ministry of Defence
Motor Industry Research Association
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Contents

Foreword

BS 6841 was prepared under the direction of the General Mechanical Engineering Standards Committee. It replaces Draft for Development DD 32:1974, which is therefore withdrawn.

ISO 2631:1985, being broadly similar to DD 32:1974, suffers similar limitations in that it does not define an adequate or reasonable procedure for measuring vibration exposures and specifies vibration limits which are not generally accepted. Growing international recognition of these problems lead to commencement of work on a revision of the International Standard during 1979. International agreement on the revision of ISO 2631 is not yet complete.

The principal differences between BS 6841 and DD 32 (and, therefore, between BS 6841 and ISO 2631:1985) are the provision of greater guidance on vibration effects without defining vibration limits, the elimination of the concept of fatigue-decreased proficiency, the inclusion of a simple time-dependency and a method of assessing repeated shocks and intermittent vibration (i.e. the vibration dose value), the modification and more complete definition of necessary frequency weightings, the definition of a standard means of assessing the discomfort caused by rotational vibration on the seat and translational vibration at the feet and seat back of seated persons, and the inclusion of more quantitative guidance on motion sickness (i.e. the motion sickness dose value).

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 24, 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.

1 Scope

Transport (air, land and water), machinery (e.g. in industry and agriculture) and industrial activities (such as piling and blasting) expose the human body to mechanical vibration and repeated shock.

This British Standard guide gives methods for quantifying vibration and repeated shocks in relation to human health, interference with activities, discomfort, the probability of vibration perception and the incidence of motion sickness.

The guide is applicable to motions transmitted to the body as a whole through the supporting surfaces: the feet of a standing person, the buttocks, back and feet of a seated person or the supporting area of a recumbent person. Vibration is often complex, containing many frequencies, occurring in several directions and changing over time.

Vibration limits are not presented. However, the methods have been given so that they may be used as the basis of limits which may be prepared separately. Various appendices provide current information on the possible effects of vibration.

The guidance is intended to be a fair compromise based on the available data and should satisfy the need for recommendations which are simple and suitable for general applications. The guidance is presented in numerical terms to avoid ambiguity and to encourage precise measurements. When using the recommendations it is important to bear in mind the restrictions placed on their application. More precise information may sometimes be obtained from the scientific literature.

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

2 Effects of whole-body vibration and repeated shock

2.1 General

Exposure to whole-body vibration causes a complex distribution of oscillatory motions and forces within the body. This may cause unpleasant sensations giving rise to discomfort or annoyance, result in impaired performance (e.g. degraded vision) or present a health risk (e.g. tissue damage or deleterious physiological change).

There are many factors which influence human response to vibration. The variables include the following.

Intrinsic variables

Population type (age, sex, size, fitness, etc.)
Experience, expectation, arousal, motivation, financial involvement
Body posture
Activities

Extrinsic variables

Vibration magnitude
Vibration frequency
Vibration axis
Vibration input position
Vibration duration
Seating, restraints, etc.
Other environmental influences (noise, heat, acceleration, light)

The four principal effects of vibration are considered to be:

a) degraded health;
b) impaired activities;
c) impaired comfort;
d) motion sickness.

2.2 Effects on health

Any part of the body may be injured by exposure to a sufficient magnitude of vibration. The parts of the body most likely to be injured during exposure to whole-body vibration will depend on the distribution of motion within the body and this will depend on the vibration frequency and axis and the coupling of the body to the vibrating source.

The probabilities and extents of particular health effects from prolonged exposures to whole-body vibration have not been established. There is a shortage of conclusive evidence relating specific injuries to definite causes. Therefore, it is not yet possible to provide a definitive dose-effect relationship between whole-body vibration and injury or health damage.

Biodynamic models and a knowledge of the physical properties of body tissue may be used to predict injury. Subjective data concerning vibration magnitudes which cause discomfort and pain may give some indication of the possibility of injury for various conditions, although it is recognised that sensations may not necessarily correlate with pathological damage.

In this standard, data from all of the above methods have been used to provide the best possible general guidance on methods of assessing vibration and shock with respect to impaired health.

NOTE Epidemiological studies suggest that back complaints are associated with exposure to prolonged periods of vibration and repeated shock but there are currently inadequate data to define a precise dose-effect relationship. Similarly, it is not yet possible to provide a definitive dose-effect relationship between whole-body vibration and any other injury.

2.3 Effects on activities

Vibration of the body may affect:

a) the acquisition of information via the senses;

b) information processing;

c) levels of arousal, motivation or fatigue;

d) intentional actions.

Vision is the perceptual mechanism most easily affected by vibration since even small movements of an image on the retina of the eye can degrade visual acuity. There is some evidence that the senses of touch and hearing may also be influenced by vibration but the effects are often small. The perception of body orientation and postural stability can also be affected by vibration.

There is little evidence that whole-body vibration directly affects cognitive processes. It is often difficult to separate direct effects from those caused by changes in arousal or motivation.

Arousal, motivation and fatigue are aspects of the behavioural state of an individual and, although they are not readily quantifiable, their effects can be very great. Vibration has been observed both to improve and to reduce task performance. This may be because it fatigues or arouses or, because of increased task difficulty, motivates. At present, these effects of vibration cannot be reliably predicted and are not quantified in this standard.

Actions performed by a person are often accomplished by speech or movements of the hands or feet. Whole-body vibration may cause a modulation of speech but under normal listening conditions this does not degrade intelligibility. Where an activity requires fine movements of the limbs, whole-body vibration can have a large effect on proficiency. Tasks involving gross locomotor movements, or lifting or carrying, are most likely to be affected by low frequency vibration. The precise effects of vibration on task performance are highly dependent on the task characteristics: detailed guidance cannot be provided in this standard.

2.4 Effects on comfort

The complex distribution of oscillatory motion and force within the body during whole-body vibration produces complex sensations. The location and character of the sensations vary greatly according to the vibration frequency, axis and other factors.

In this standard the term "discomfort" is applied to the sensations arising directly from the vibration. A wider term is sometimes used in transportation systems to include reactions to other aspects of the environment (e.g. noise) and the effects of motion on common activities (e.g. reading and writing).

In this standard a method is defined to enable the discomfort of two or more complex vibrations to be compared. Whether a degree of discomfort is acceptable will depend on many factors. A limiting value should be selected by the user for specific applications: different limits for discomfort will apply in different circumstances.

For some applications, knowledge of whether vibration can be perceived is useful. This standard therefore also defines the probability of perceiving low magnitudes of whole-body vibration.

NOTE Although pleasurable sensations may be experienced with some types of oscillatory motion they are outside the scope of this standard and they will not usually be confused with those causing discomfort.

2.5 Motion sickness

Low frequency (less than about 0.5 Hz) oscillation of the body can cause the motion sickness syndrome characterized principally by pallor, sweating, nausea and vomiting. Although other types of stimulation may cause similar symptoms, this standard is solely concerned with kinetosis (i.e. motion sickness) due to low frequency vertical z-axis oscillation of the human body. The guidance is formulated so as to enable the probability of vomiting in a given population to be predicted.

3 Vibration measurement and frequency weighting

3.1 Units of vibration magnitude

The primary quantity for expressing vibration magnitude is the weighted root-mean-square acceleration in $m \cdot s^{-2}$ for translational vibration and $rad \cdot s^{-2}$ for rotational vibration.

Root-mean-square (r.m.s.) measures of acceleration may be used when the crest factor does not exceed 6.0. However the severity of motions which are intermittent or contain occasional high peak values and have crest factors in excess of 6.0 will often by underestimated by r.m.s. measures. This standard gives alternative methods for the evaluation of these motions.

NOTE The crest factor of the motion is to be determined from the peak and r.m.s. value of the acceleration after it has been frequency weighted by the appropriate frequency weighting network. [Crest factor = (weighted peak acceleration)/(weighted r.m.s. acceleration)]. The peak and r.m.s. values are to be determined over the full period of vibration exposure which it is desired to assess.

3.2 Direction of measurement

Vibration should be measured according to a coordinate system centred at the interface with the body. The principal relevant basicentric systems are shown in Figure 1.

In many situations it is not feasible to obtain precise alignment of vibration transducers with the preferred basicentric axes. The sensitive axes of transducers may deviate from the preferred axes by up to 20 degrees where necessary. Where a person is seated on an inclined seat the relevant orientation should be determined by the axes of the body and the z-axis may not be vertical.

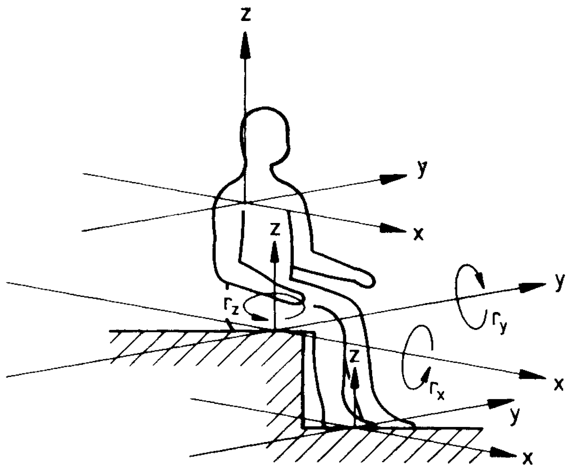
Transducers located at one measurement position have to be orthogonally positioned. Translational accelerometers orientated in different axes at a single measurement position should be as close together as possible.

3.3 Preferred measurement locations

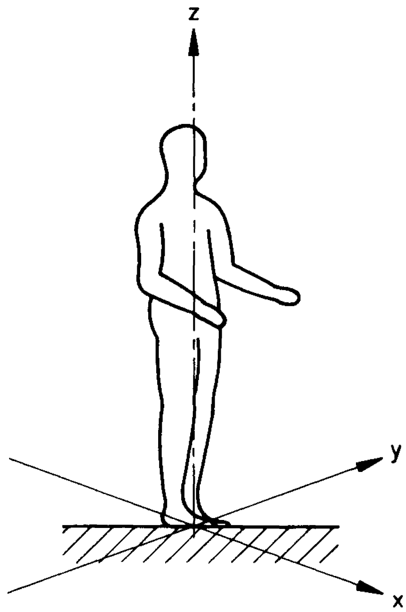
Transducers should be located so as to indicate the vibration at the interface between the human body and the source of its vibration.

Where vibration enters the body from a rigid surface (e.g. floor or hard seat) it is sufficient to measure the motion of the surfaces adjacent to the principal areas of contact between the body and the surface (e.g. within 100 mm of the centre of this area).

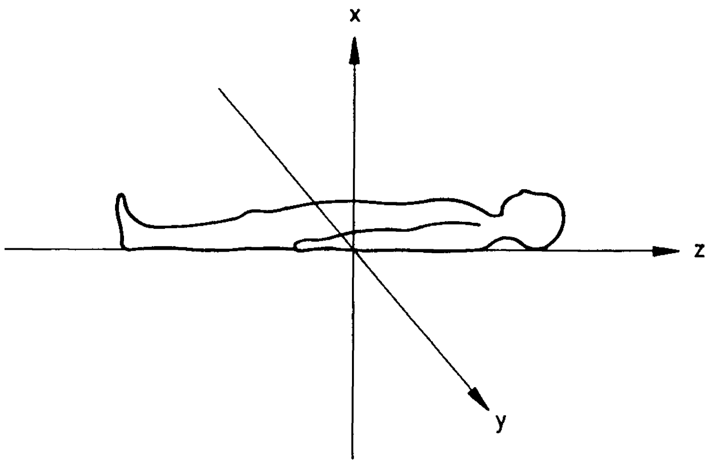
Where vibration enters the body from a non-rigid or resilient material (e.g. seat cushion or couch) it is necessary to interpose the transducer between the person and the principal contact areas of the surface. This may best be achieved by securing the transducers within a suitably formed mount. The mount should not greatly alter the pressure distribution on the surface of the resilient material.



(a) Principal basicentric axes for a seated person



(b) Basicentric axes for a standing person



(c) Basicentric axes for a prone person

Figure 1 — Basicentric axes of the human body

Measurements obtained on non-rigid surfaces require that a live subject of appropriate characteristics adopts the normal position for the environment. Currently available dummies and representative masses do not normally provide the correct dynamic response since the mechanical impedance of man is not that of a pure mass.

NOTE 1 Two commonly used designs for accelerometer mounts will be found in the Society of Automotive Engineers standards SAE J1013 and SAE 770253[1].

[1] Society of Automotive Engineers standards may be purchased from Enquiry Section, BSI, Linford Wood, Milton Keynes MK14 6LE.

NOTE 2 The principal areas of contact between the body and a vibrating surface may not always be self evident. Clauses in this standard define three principal areas for seated persons: the supporting seat surface, the seat-back and the feet. Measurements on the supporting seat surface should be made beneath the ischial tuberosities. Measurements on the seat-back should be made at the position with the greatest effective vibration in contact with the body. Measurements at the feet should be made on the surface on which the feet are most often supported. Similar approaches should be used for other axes. In all cases the method of measurement should be fully reported.

NOTE 3 Where measurements at the person-seat interface are not practical, evaluation of the effects of vibration may be made on the basis of measurements taken at a rigid portion of the vehicle or building structure such as the centre of rotation or the centre of gravity. The use of such measurements for predicting human response is not recommended. If their use is unavoidable, the transfer function between the measurement position and the body interface is to be reported.

3.4 Frequency weightings

3.4.1 *General.* The manner in which vibration affects health, activities, comfort and motion sickness is dependent on the vibration frequency. Different frequency weightings are required for the different axes of vibration and for the different effects of vibration on the body (see Table 1).

The frequency weightings may be realized by either analogue or digital methods. They are defined in a mathematical form familiar to filter designers. The responses of the weightings are defined by both the expected filter responses and asymptotic approximations to the curves. (The asymptotic approximations have slopes of – 6.0, 0.0, + 6.0 and + 12.0 dB per octave.)

In addition to the frequency weightings it is necessary to define band-limiting filters.

3.4.2 *Frequency band limitation.* Lower and upper frequency band limitations are achieved by two pole high-pass and low-pass filters respectively with Butterworth characteristics having an asymptotic slope of 12 dB per octave. The corner frequencies of the band-limiting filters are one-third of an octave outside the nominal frequency range of the relevant band.

Frequency weightings W_b, W_c, W_d, and W_e are to be used to assess vibration over the frequency range 0.5 Hz to 80 Hz: they have high and low-pass band-limiting filters at 0.4 Hz and 100 Hz respectively. Frequency weighting W_f is to be used for motions over the range 0.1 Hz to 0.5 Hz and has high and low-pass band-limiting filters at 0.08 Hz and 0.63 Hz respectively. Frequency weighting W_g may be applied over the range 1.0 Hz to 80 Hz and has band-limiting filters at 0.8 Hz and 100 Hz.

Table 1 — Outline guide to the application of frequency weightings

Clause reference	4	5		6		7
Frequency weighting	**Health**	**Hand control**	**Vision**	**Discomfort**	**Perception**	**Motion sickness**
W_b	z-seat	—	—	z-seat x-, y-, z-feet z-standing vertical lying	z-seat — z-standing vertical lying	—
W_c	x-back	—	—	x-back	—	—
W_d	x-seat y-seat	x-seat y-seat	— —	x-seat y-seat x-, y-standing horizontal lying y-, z-back	x-seat y-seat x-, y-standing horizontal lying	—
W_e	—	—	—	r_x, r_y, r_z seat	—	—
W_f	—	—	—	—	—	z-vertical
W_g	—	z-seat	z-seat	—	—	—

3.4.3 *Frequency weightings.* Table 2 gives the frequency weightings required to give an approximate quantification of the relative effects of different vibration frequencies on human health, performance, comfort, perception and motion sickness.

NOTE 1 The phase is defined by the filter characteristics and although it is not specifically employed in the vibration analysis procedure it may affect the crest factor.

NOTE 2 The frequency weightings defined by the equations should normally be used. Asymptotic approximations to the weightings (using straight line approximations) are presented in Table 3 for approximate use only.

NOTE 3 Frequency weighting W_g is consistent with the weighting for z-axis vibration given in BS 6472, ISO 2631 and ISO 8041 over the range 1.0 Hz to 80 Hz. In this British Standard, weighting W_g is only used to quantify the severity of motions which may interfere with activities when the dominant motion is in the range from 1.0 Hz to 80 Hz.

NOTE 4 Frequency weighting W_d is similar to the frequency weighting given for x- and y-axis vibration in BS 6472, ISO 2631 and ISO 8041, other than for the extension from 1.0 Hz to 0.5 Hz.

3.4.4 *Tolerances.* Within the nominal frequency bands and one-third of an octave in from the frequency limits, the tolerance of the combined frequency weighting and band limiting should be less than ± 1 dB. Outside this range the tolerance should be less than ± 2 dB. One octave outside the nominal frequency bands the attenuation may extend to infinity.

3.5 Reporting of vibration conditions

This standard has been formulated so as to simplify and standardize the reporting, comparison and assessment of vibration conditions. Proper use of the standard should result in clear documentation of results. This will involve a reference to the appropriate clauses and appendices of the standard and one or more of the frequency weighting networks.

Where variations on the methods given in this standard are used it is important that the differences are clearly reported.

The specification of the severity of complex vibration conditions by one, or a few, values is convenient and often essential. If possible, reports should also include information on, for example, the frequency content (i.e. vibration spectra), amplitude distributions, vibration axes, crest factors and how conditions change over time. Other variables which may influence the effects of vibration, as detailed in **2.1**, should also be reported.

Table 2 — Characteristics of band-limiting and band-pass filters for frequency weightings

Weighting	Band-limiting			Frequency weighting							
	f_1	f_2	Q_1	f_3	f_4	f_5	f_6	Q_2	Q_3	Q_4	K
	Hz	Hz		Hz	Hz	Hz	Hz				
W_b	0.4	100	0.71	16	16	2.5	4	0.55	0.90	0.95	0.4
W_c	0.4	100	0.71	8	8	—	—	0.63	—	—	1.0
W_d	0.4	100	0.71	2	2	—	—	0.63	—	—	1.0
W_e	0.4	100	0.71	1.0	1.0	—	—	0.63	—	—	1.0
W_f	0.08	0.63	0.71	∞	0.250	0.0625	0.10	0.86	0.8	0.8	0.4
W_g	0.8	100	0.71	1.5	5.3	—	—	0.68	—	—	0.42

The band-limiting filters are given by:

$$H_b(s) = \frac{s^2 \cdot 4\pi^2 f_2^2}{\left(s^2 + \frac{2\pi f_1}{Q_1} \cdot s + 4\pi^2 f_1^2\right)\left(s^2 + \frac{2\pi f_2}{Q_1} \cdot s + 4\pi^2 f_2^2\right)}$$

The frequency weightings W_c, W_d, W_e, and W_g are given by:

$$H_w(s) = \frac{(s + 2\pi f_3)}{\left(s^2 + \frac{2\pi f_4}{Q_2} \cdot s + 4\pi^2 f_4^2\right)} \cdot \frac{2\pi K \cdot f_4^2}{f_3}$$

and they may be realised by two pole filters.

The weightings W_b and W_f are given by:

$$H_w(s) = \frac{(s + 2\pi f_3)\left(s^2 + \frac{2\pi f_5}{Q_3} \cdot s + 4\pi^2 f_5^2\right)}{\left(s^2 + \frac{2\pi f_4}{Q_2} \cdot s + 4\pi^2 f_4^2\right)\left(s^2 + \frac{2\pi f_6}{Q_4} \cdot s + 4\pi^2 f_6^2\right)} \cdot \frac{2\pi K f_4^2 \cdot f_6^2}{f_3 \cdot f_5^2}$$

where:

values of f_n (n = 1 to 6) designate resonance frequencies;

Q_n (n = 1 to 4) designate selectivity;

K is a constant gain; and

$H(s)$ is the transfer function of the filter (s is the Laplace operator).

Table 3 — Asymptotic approximations to the frequency weightings given in Table 2

Frequency	W_b	W_c	W_d	W_e	W_f	W_g
0.1	—	—	—	—	0.800 0.711	—
0.125	—	—	—	—	1.000 0.913	—
0.16	—	—	—	—	1.000 1.027	—
0.2	—	—	—	—	1.000 1.008	—
0.25	—	—	—	—	1.000 0.859	—
0.315	—	—	—	—	0.630 0.607	—
0.4	—	—	—	—	0.391 0.357	—
0.5	0.400 0.334	1.000 0.843	1.000 0.853	1.000 0.862	0.250 0.192	—
0.63	0.400 0.367	1.000 0.929	1.000 0.944	1.000 0.939	—	—
0.8	0.400 0.381	1.000 0.972	1.000 0.992	1.000 0.941	—	—
1.0	0.400 0.385	1.000 0.991	1.000 1.011	1.000 0.880	—	0.500 0.424
1.25	0.400 0.386	1.000 1.000	1.000 1.008	0.800 0.772	—	0.559 0.503
1.6	0.400 0.392	1.000 1.007	1.000 0.968	0.625 0.632	—	0.632 0.589
2.0	0.400 0.417	1.000 1.012	1.000 0.890	0.500 0.511	—	0.707 0.677
2.5	0.500 0.494	1.000 1.017	0.800 0.776	0.400 0.409	—	0.791 0.779
3.15	0.630 0.662	1.000 1.022	0.635 0.642	0.317 0.323	—	0.887 0.897
4.0	0.800 0.889	1.000 1.024	0.500 0.512	0.250 0.253	—	1.000 1.004
5.0	1.000 1.025	1.000 1.013	0.400 0.409	0.200 0.202	—	1.000 1.050
6.3	1.000 1.055	1.000 0.974	0.317 0.323	0.159 0.160	—	1.000 1.009
8.0	1.000 1.025	1.000 0.891	0.250 0.253	0.125 0.125	—	1.000 0.890
10.0	1.000 0.974	0.800 0.776	0.200 0.202	0.100 0.100	—	0.800 0.750
12.5	1.000 0.907	0.640 0.647	0.160 0.161	0.080 0.080	—	0.640 0.615
16.0	1.000 0.810	0.500 0.512	0.125 0.125	0.063 0.063	—	0.500 0.486
20.0	0.800 0.708	0.400 0.409	0.100 0.100	0.050 0.050	—	0.400 0.391
25.0	0.640 0.600	0.320 0.325	0.080 0.080	0.040 0.040	—	0.320 0.313
31.5	0.508 0.492	0.254 0.256	0.063 0.063	0.032 0.032	—	0.254 0.248
40.0	0.400 0.393	0.200 0.199	0.050 0.049	0.025 0.025	—	0.200 0.194
50.0	0.320 0.313	0.160 0.156	0.040 0.039	0.020 0.019	—	0.160 0.153
63.0	0.254 0.239	0.127 0.118	0.032 0.030	0.016 0.015	—	0.127 0.116
80.0	0.200 0.171	0.100 0.084	0.025 0.021	0.013 0.011	—	0.100 0.083

NOTE The response of filters with band-limitation is shown beneath the asymptotic approximation.

4 Guide to the evaluation of vibration and repeated shock with respect to effects on health

4.1 General

Clause **4** concerns the effects of vibration and repeated shocks on the health of persons exposed to whole-body vibration during travel, at work and during leisure activities. A procedure is given for estimating the relative probability that different types of vibration and repeated shocks will impair health.

The guidance is applicable to vibration and repeated shock in the frequency range 0.5 Hz to 80 Hz which is transmitted to the body as a whole through the supporting surfaces: the buttocks of a seated person or the feet of a standing person. It also applies to fore-and-aft (x-axis) motions of a backrest to a seat. The guidance does not apply to local injuries to the hand or arm due to vibration from hand held tools or workpieces.

Most of the available relevant scientific information is currently limited to the effects of vertical vibration in the z-axis from a supporting seat surface. For other directions of motion there is little direct information. The recommendations given here are influenced by subjective data obtained in laboratories and by data from field studies. Even for vertical vibration in the z-axis it is not possible to specify with any precision either the type or the probability of any injury that may occur due to excessive vibration exposures.

The guidance provided is therefore a consensus of current opinion on the likely relative importance of physical factors associated with the conditions that might cause injury or disease. The guidance takes into account knowledge of the magnitudes of vibration that occur in different occupations, the biodynamic response of the body and the severity of sensations that occur during exposure to vibration.

NOTE 1 Clause **4** does not present vibration limits. Appendix A gives a consensus of opinion on possible effects of vibration magnitudes and durations.

NOTE 2 Body positions and seating conditions may be expected to be particularly important in determining the hazardous effects of vertical (z-axis) whole-body vibration. However, these factors differ in each application and are not enumerated in this standard.

4.2 Vibration evaluation guide: effects of vibration on health

4.2.1 *Frequency weighting.* The frequency weightings required for the evaluation of the whole-body effects of vibration on health are W_b, W_c and W_d. They should be applied to the measurements made in the various vibration axes:

x-axis on supporting surface	weighting W_d
y-axis on supporting surface	weighting W_d
z-axis on supporting surface	weighting W_b
x-axis on seat backrest	weighting W_c

The supporting surface is that on a seat for seated persons or on the floor for a standing person.

4.2.2 *Evaluation of simple and complex vibration spectra.* In order to characterize vibration magnitudes with respect to health by a single quantity the overall vibration acceleration signal should be weighted as given in **4.2.1**.

For vibration exposures of constant magnitude and with crest factors below 6.0, the root-mean-square of the frequency-weighted acceleration should be determined over a period of at least 60 s by linear integration.

NOTE When either the crest factors exceed 6.0, or the vibration has variable magnitude, or the motion contains occasional peaks, or the motion is intermittent, the vibration dose value procedure given in Appendix A should be used.

4.2.3 *Vibration direction and body orientation.* The guidance applies only to x-, y- and z-axis vibration on a supporting seat surface and x-axis seat-back vibration. High magnitudes of vibration which occur in other axes should be measured and reported separately.

NOTE 1 The method of evaluation is applicable to erect standing postures. However, slight bending of the knees can affect the transmission of vibration to standing persons so this application will not always be appropriate.

NOTE 2 For recumbent postures it is tentatively recommended that weightings W_b and W_d are used for the vertical and horizontal axes of vibration respectively. It is assumed that the head is never in direct contact with the full vibration magnitude.

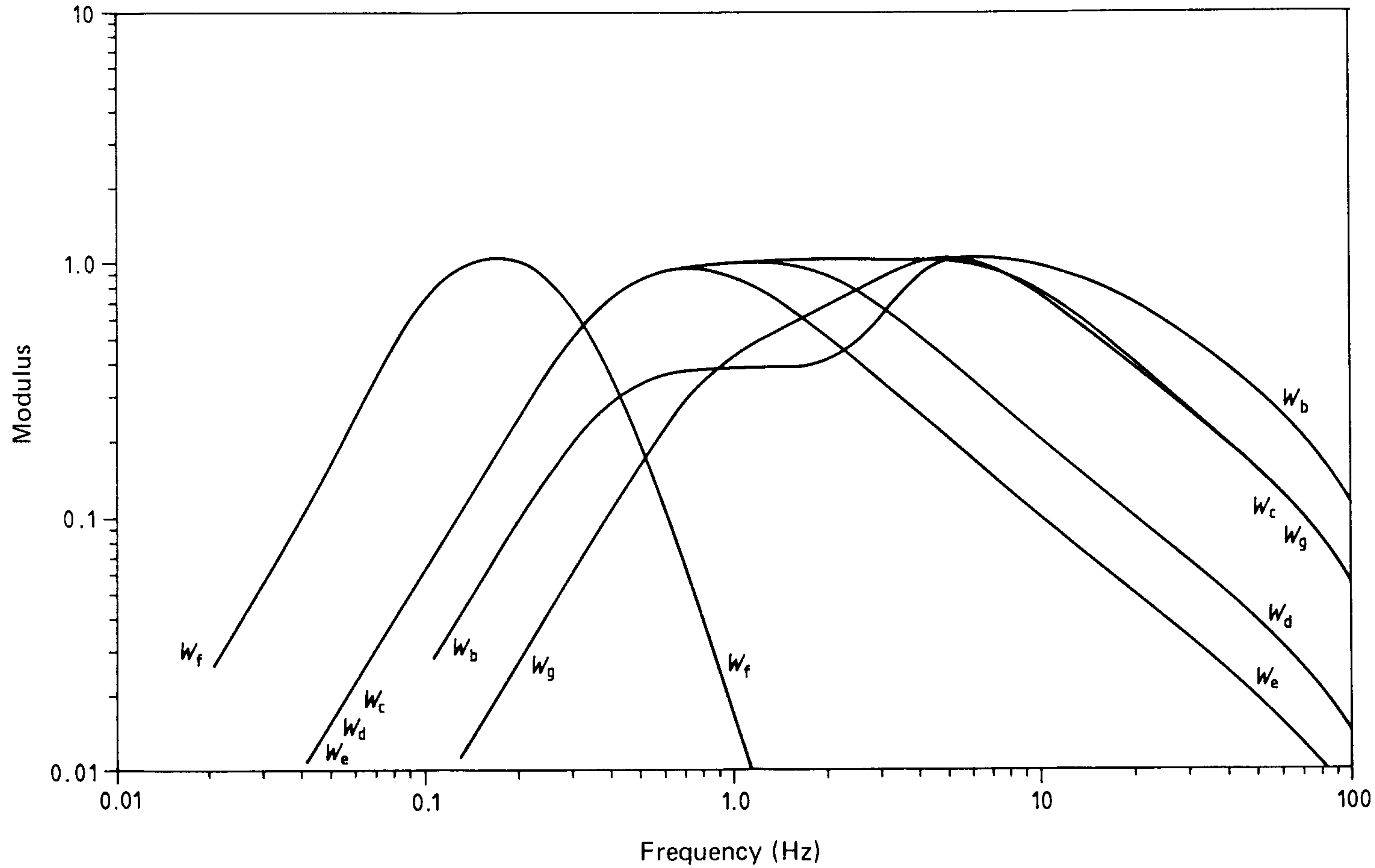


Figure 2 — Moduli of the frequency weightings with band-limiting filters

4.2.4 *Guide to effect of weighted vibration magnitudes.* The procedures given in this standard encourage the uniform reporting of vibration conditions and make it possible to predict the relative severity of different environments. Vibration limits are not given.

NOTE Appendix A gives information on the interpretation of weighted vibration magnitudes with respect to health and gives a relation between vibration magnitude and exposure time.

5 Guide to the evaluation of vibration with respect to effects on human activities

5.1 Introduction

Clause **5** concerns the effect on human activities of vibration transmitted to the human body in the frequency range 1.0 Hz to 80 Hz.

The guidance is primarily applicable to vibration transmitted to the seated body through the supporting seat surface. The procedures indicate the relative importance of vibration characteristics (the vibration magnitude, frequency and axis) with respect to the effects of vibration on the performance of activities.

Most available information is concerned with the specific effects of vibration on the coordinated control of hand movements and vision. Humans have a great ability to compensate for the effects of adverse environments.

Limitations in the available data are such that no precise predictions are possible concerning effects on activities such as speech, postural control, cognitive processes and attention. Similarly, there can be no quantification of fatigue or any consequent effects on performance which may occur during or following prolonged vibration exposures.

NOTE 1 Clause **5** does not present vibration limits. Appendix B gives a consensus of opinion on possible effects of vibration on activities.

NOTE 2 The procedure described in clause **5** is only applicable to vibration with dominant motions in the frequency range 1.0 Hz to 80 Hz.

NOTE 3 The guidance is primarily intended for environments with low crest factor motions and for predicting the effects on activities which occur during vibration exposure. Where the crest factor exceeds 6.0, or when only long term effects of vibration are of interest, additional guidance should be obtained from the scientific literature.

NOTE 4 The evaluation procedure has been designed so that for motions having their dominant energy in the range 1.0 Hz to 80 Hz the weighted values given by the procedure described in clause **5** will be similar to those obtained using ISO 2631:1985. However, it is not recommended that the acceptability of any vibration should be determined by reference to the “fatigue — decreased proficiency limits” given in that International Standard.

5.2 Non-specific effects of vibration on performance

Vibration has been observed to have some non-specific effects (i.e. effects which also occur due to other adverse conditions). However the effects have been task-specific and difficult to quantify and predict. They appear to be dependent on factors such as arousal and motivation.

With cognitive tasks the effects of low magnitude vibration on a task may not be reflected in performance scores. However subjects may be aware of the effect of the vibration environment and may be capable of estimating the increased difficulty associated with the vibration. This information may be elicited by subject ratings but may not be reflected in performance unless the vibration duration is very great.

In addition to external factors, such as the consequences of poor performance, the magnitude and importance of non-specific stress effects will vary according to the demands of the complete task on the individual. Task duration (as opposed to vibration duration) may be an important factor.

Vibration can be an arousing stimulus and, in some circumstances, leads to improved performance. This is most likely to occur when a person is engaged in the continuous performance of a task which is itself not particularly arousing.

5.3 Vibration evaluation guide

5.3.1 *Introduction*

5.3.1.1 *Hand manipulation and control.* The effects of vibration on hand manipulation depend on the vibration magnitude, frequency, direction and its principal point of contact with the body. In addition, the characteristics of the task being performed will determine the extent of any influences of the vibration. The gain (i.e. sensitivity) of the control (or device) held in the hand, the orientation of its sensitive axes, its shape, the system dynamics and the form of associated displays will all combine to determine the effects of vibration.

Clause **5** therefore describes a simple measurement procedure which may give appropriate weight to different vibration frequencies for some hand-control tasks. The user of this standard should decide whether this weighting is appropriate by considering the sensitivity of the relevant system and the manner in which it responds to disturbances at different frequencies.

5.3.1.2 *Vision.* The effects of vibration on vision depend on the vibration magnitude, frequency and direction. They vary according to the viewing distance, illumination, contrast, angular subtense and form of viewed objects. They also depend on whether the object, the human body or both are vibrating. This standard describes a uniform method of expressing vibration magnitudes with respect to their possible effects on vision but does not attempt to elaborate the detailed and complex relation between all of the relevant parameters.

Available information shows that large effects on the resolution of visual detail normally only occur during z-axis vertical vibration of the whole-body or y- and z-axis vibration of viewed objects. This application of the standard is therefore restricted to these axes.

5.3.2 *Frequency weightings.* Two frequency weightings (W_d and W_g) are required for the general measurement of whole-body vibration with respect to its effect on activities. The weightings should be applied to measurements made in the three vibration axes:

x-axis on seat surface	weighting W_d
y-axis on seat surface	weighting W_d
z-axis on seat surface	weighting W_g

NOTE 1 There are experimental data showing greater effects on hand control of y-axis vibration than x-axis vibration because of the greater transmission of vibration to the hand and the relative importance of this axis to task performance.

NOTE 2 In many situations there is vibration of both the body and the hand control. Provisionally it is recommended that the effect of the independent vibration of a hand control may also be assessed by the application of weighting W_d to x- and y-axis vibration and W_g to z-axis vibration measured on controls. The coupling of the hand with some controls can increase the magnitude of x- and y-axis vibration, so multiplying factors may be needed before assessing the importance of these motions by reference to Appendix B (i.e. the frequency-weighted acceleration magnitude on a control should be multiplied by an appropriate factor before the effects are assessed). A relevant vibration measurement on a hand- or finger-operated control can only normally be obtained when the control is being held in the hand.

NOTE 3 Although x- and y-axis vibration on a supporting seat surface do not usually affect vision it is recommended that the magnitudes of these motions should always be determined and reported using frequency weighting W_d. Vibration of a backrest (particularly in the x-axis) may influence visual performance. Vibration measurements on backrests should be obtained in accordance with procedures described in clause **6**.

NOTE 4 In many situations there is vibration of both the body and viewed objects. Provisionally, it is recommended that the effect of independent vibration of a viewed object may also be assessed by the application of weighting W_g to y- and z-axis vibration measured on the object or display. (This may often over-emphasise the importance of vibration at frequencies above about 8 Hz.)

5.3.3 *Evaluation of simple and complex vibration spectra.* In order conveniently to characterize the effect of a vibration environment on activities by a single quantity, the true r.m.s. value should be determined for each frequency-weighted acceleration signal.

5.3.4 *Vibration in more than one direction.* The weighted values in every axis should be calculated as in **5.3.3** and quoted separately.

NOTE 1 A total manual control decrement might be determined from the root-sums-of-squares of the weighted acceleration in all three axes. However, for many applications this will not be useful since the characteristics of the task will be such that its sensitivity to motion will be different for each axis of motion.

NOTE 2 It should be recognized that the vibration in one direction on a seat may give rise to error in hand manipulation in a different axis.

NOTE 3 When both the human body and the object being viewed are exposed to the same vertical vibration, the effect on performance may be less than if one or the other is vibrating alone only when the dominant vibration frequency is below about 2.5 Hz.

NOTE 4 There is evidence that motion occurring simultaneously in two axes has a considerably greater effect on vision than motion in either axis alone. The effect is dependent on the phase relationship between the two motions.

5.3.5 *Evaluation of time-varying and repeated shock motions.* The measurement procedure is restricted to conditions where the vibration conditions are approximately constant. Increases and decreases in vibration magnitude will normally produce corresponding decreases and increases in performance. Vibration measurements should be obtained during periods when the vibration statistics may be considered stationary and the crest factors are below 6.0. No time-dependency of vibration effects is given.

NOTE 1 Most documented effects of vibration are confined to the specific and immediate effects of vibration on hand manipulation and vision and therefore do not vary over the stimulus duration.

NOTE 2 The speed and accuracy of task performance will often vary with the time over which the task is performed. Vibration may interact with any such time-dependency causing either an improved or degraded performance with increased time. Available information suggests that such effects of vibration over periods up to one or two hours may often be due to changes in arousal and motivation.

5.3.6 *Guide to effects of weighted vibration magnitudes.* The procedures described in this standard encourage the uniform reporting of vibration conditions and allow meaningful comparisons of the relative severity of different environments. Vibration limits are not given in this standard.

NOTE Appendix B provides information on the interpretation of weighted vibration magnitudes with respect to hand control activities and human vision.

6 Guide to the evaluation of vibration and repeated shock with respect to discomfort and perception

6.1 Introduction

Clause **6** concerns the estimation of the likely effect on the comfort of people in normal health who are exposed to whole-body vibration and repeated shocks during travel, at work or during leisure activities. It also describes measurement procedures for predicting perception thresholds for whole-body vibration.

For the **discomfort of seated** people this clause applies to vibration and repeated shock in the frequency range 0.5 Hz to 80 Hz which occurs in all six axes on the seat pan (three translational: x-axis, y-axis and z-axis and three rotational: r_x-axis, r_y-axis, and r_z-axis). It also applies to the three translational (x-, y- and z-) axes at the seat-back and feet of seated people.

For the **discomfort of standing and recumbent** people, guidance is provided for vibration and repeated shock occurring in the three translational (x-, y- and z-) axes on the principal surface supporting the body.

The evaluation procedures make it possible to estimate (from the vibration magnitude, frequency and direction) the likely relative effects on comfort of different types of vibration.

For the **perception of vibration by standing, sitting and recumbent** people, guidance is provided for periodic and random vibration occurring in the three translational (x-, y- and z-) axes on the principal surface supporting the body.

NOTE 1 Clause **6** does not present vibration limits. In practice, limits for comfort will depend on their application. Appendix C gives a consensus of opinion on the possible effects on comfort of various magnitudes of vibration. Thresholds of perception are also given in that appendix.

NOTE 2 In the context of this standard, "discomfort" refers to sensations arising directly from the vibration.

NOTE 3 People differ in their response to vibration and individuals may have different reactions at different times. Thus two motions, which are assessed as equally severe by the recommended evaluation procedures, may have noticeably different effects. Individuals will sometimes disagree on which of two motions is worse and variables such as posture, subject activity and experience can have large effects. While the evaluation procedure is the best general guidance that can be offered it is possible that, for individual subjects, particular situations, or specific activities, some more accurate method might be determined by suitable research.

NOTE 4 The procedure specified in this standard is based upon laboratory research and field surveys.

6.2 Vibration evaluation guide: comfort

6.2.1 *Frequency weightings.* The frequency weightings required for the prediction of the effects of vibration on comfort are W_b, W_c, W_d and W_e. For a seated person these weightings should be applied as follows:

x-axis (supporting seat surface vibration) W_d

y-axis (supporting seat surface vibration) W_d

z-axis (supporting seat surface vibration) W_b

NOTE 1 In some environments the comfort of a seated person is affected by rotational vibration on the seat, by vibration of the backrest or by vibration at the feet. Vibration at these positions may be assessed using the following frequency weightings:

r_x-axis on supporting seat surface W_e (multiplying factor = 0.63)

r_y-axis on supporting seat surface W_e (multiplying factor = 0.4)

r_z-axis on supporting seat surface W_e (multiplying factor = 0.2)

x-axis on seat-back W_c (multiplying factor = 0.8)

y-axis on seat-back W_d (multiplying factor = 0.5)

z-axis on seat-back W_d (multiplying factor = 0.4)

x-axis at the feet W_b (multiplying factor = 0.25)

y-axis at the feet W_b (multiplying factor = 0.25)

z-axis at the feet W_b (multiplying factor = 0.40)

NOTE 2 For standing persons the use of the same weightings employed for translational seat vibration is provisionally recommended:

x-axis (floor vibration) W_d
y-axis (floor vibration) W_d
z-axis (floor vibration) W_b

NOTE 3 For recumbent people it is provisionally recommended that the following weightings should be used:

vertical vibration of supporting surface W_b
horizontal vibration of supporting surface W_d

NOTE 4 Unless specified, the multiplying factors are unity. The weighted acceleration (in $m\cdot s^{-2}$ for translation vibration and $rad\cdot s^{-2}$ for rotational vibration) should be multiplied by these factors to produce weighted acceleration signals.

NOTE 5 At vibration frequencies above approximately 10 Hz, rotational vibration at the point of entry to the body will have an effect which is due to the translational motion caused by the rotation. Weightings for rotational vibration are therefore only considered necessary below 10 Hz. However, the weighting is given for higher frequencies for consistency.

6.2.2 *Evaluation of simple and complex vibration spectra.* To characterise the discomfort of a vibration environment by a single quantity, the r.m.s. value should be determined by linear integration for each of the frequency-weighted acceleration signals.

NOTE The r.m.s. value of a frequency-weighted vibration will only give a good estimate of the effect on comfort when the crest factor of the motion is low. If the vibration contains occasional high peak values or is intermittent and the crest factor exceeds 6.0 the methods described in Appendix C should be used.

6.2.3 *Vibration in more than one direction.* The weighted values in every axis at each of the measurement points should be calculated as in **6.2.2** and quoted separately. The root sums of squares a at each measurement point may then be determined from the square root of the sums of squares of the three weighted values a_{xw}, a_{yw} and a_{zw} at each point.

$$a = (a_{xw}^2 + a_{yw}^2 + a_{zw}^2)^{1/2}$$

NOTE 1 When reporting rotational seat, or translational backrest or footrest vibration for seated persons the above procedure should be used to calculate the root sums of squares from the three components at each point. The root-sums-of-squares value for each point should be reported separately.

NOTE 2 If a weighted value determined in any axis is less than 25 % of the maximum value determined at the same point but in another axis it need not be included in the above calculations.

In many cases this will make it unnecessary to measure some, or all, of the axes of rotation on a supporting seat surface.

6.2.4 *Vibration at more than one point.* The root sums of squares values determined at separate points should be compared separately with similarly determined values in other environments and with any specifications (e.g. limits) that are specified for the system.

NOTE 1 In some environments there may be significant vibration at more than one point or there may be some combination of sitting, standing and recumbent persons. It may then be necessary to consider the total effect of all positions and postures in all axes.

NOTE 2 For a seated person an overall value may be determined from the root sums of squares of the four vector sums (i.e. translation and rotation on the seat and translation at the back and feet).

6.2.5 *Evaluation of time-varying and repeated shock motions.* The procedures described in clause **6** are applicable when the vibration conditions are effectively stationary and the minimum analysis period is approximately 60 s.

Where a complete exposure consists of various periods of vibration with different characteristics there should be separate measurements of each period. Vibration specifications devised for the environment may limit the maximum r.m.s. level for any period or an average obtained over the full vibration exposure.

NOTE Appendix C describes a procedure which may be used to determine either the average or total effect of a vibration or repeated shock exposure comprising various magnitudes, having high crest factors, or containing intermittent vibration.

6.2.6 *Duration (exposure time) of vibration.* The vibration exposure duration is only one of many factors which can influence comfort. The duration of exposure should be considered when determining vibration specifications (e.g. limits) concerned with comfort.

NOTE A procedure which may be used to compare the relative discomfort produced by vibrations of different durations is defined in Appendix C.

6.2.7 *Guide to effects of weighted vibration magnitude.* The procedures described in this standard encourage the uniform reporting of vibration conditions and allow meaningful comparisons of the relative severity of different environments. Vibration limits are not given.

NOTE Appendix C provides information on the interpretation of weighted vibration magnitudes with respect to comfort.

6.3 Vibration evaluation guide: vibration thresholds

6.3.1 *Frequency weightings.* Two frequency weightings (W_b and W_d) are required for the prediction of the perceptibility of vibration. These weightings may be applied (with unity multiplying factor) to the following combinations of posture and vibration axis.

For seated persons:

x-axis (supporting seat surface vibration) W_d
y-axis (supporting seat surface vibration) W_d
z-axis (supporting seat surface vibration) W_b

For standing persons:

x-axis (floor vibration) W_d
y-axis (floor vibration) W_d
z-axis (floor vibration) W_b

For recumbent persons:

vertical vibration of supporting surface W_b
horizontal vibration of supporting surface W_d

NOTE 1 The frequency weightings apply to vibration measured at the interface with the human body. Vibration at frequencies greater than about 10 Hz will often be attenuated by chairs, beds, etc., but these may amplify the vibration at lower frequencies. The frequency weightings may therefore be over-restrictive at high frequencies if measurements are made on a floor but vibration exposure only occurs via a bed or chair.

NOTE 2 The frequency weightings are the same as those used in **6.2.1** for comfort. This approximation is generally appropriate but may underestimate the perceptibility of some higher frequencies, especially with horizontal vibration.

6.3.2 *Evaluation of simple and complex vibration spectra.* In all cases the peak value of the weighted vibration acceleration in each of the three translational axes should be reported.

6.3.3 *Vibration in more than one direction.* Evaluation of the perceptibility of vibration should be made with respect to the axis having the highest weighted value.

6.3.4 *Vibration at more than one point.* The weighted values should be determined at all points of contact between the vibration and the body. Only the greatest value is required to determine the perceptibility of the vibration.

6.3.5 *Evaluation of time-varying and repeated shock motions.* The weighted peak acceleration should be determined over any period during which the vibration occurs. This value should be used to determine the perceptibility of the vibration.

NOTE 1 Perception thresholds decrease only very slightly with increases in vibration duration up to 1 s and very little with further increases in duration. There is therefore little need to employ r.m.s. averaging or any particular time constant. When determining the peak value, r.m.s. averaging should not be employed.

NOTE 2 Although the perception threshold does not continue to decrease with increasing duration, the annoyance produced by vibration at magnitudes above threshold may continue to increase. It is recommended that the cumulative effect of long exposures or any number of intermittent exposures is expressed by the fourth root of the fourth power of the frequency-weighted acceleration multiplied by the exposure time (see Appendix A).

6.3.6 ***Perceptibility of weighted vibration magnitude***

The procedures described in this standard encourage the uniform reporting of vibration conditions and allow meaningful comparisons of the relative severity of different environments.

NOTE Appendix C provides information on the interpretation of weighted vibration magnitudes with respect to vibration perception.

7 Guide to the evaluation of low frequency vibration with respect to the incidence of motion sickness

7.1 General

Clause **7** concerns the effects of oscillatory motion on the incidence of kinetosis or motion sickness. The methods presented are primarily applicable to motion in ships and other sea vessels but may also be applied to some other motion environments.

Other clauses in this standard are primarily concerned with vibration at frequencies above 0.5 Hz. Motion in the approximate frequency range 0.1 Hz to 0.5 Hz may cause various undesirable effects including discomfort and interference with activities. However, most commonly, it produces motion sickness.

The guidance is restricted to z-axis vertical vibration only and is based on data from sitting males and females who have not adapted to the motion.

It is well established that large differences in response to motion occur both between and within individuals.

The incidence of motion sickness is affected by many factors such as age, sex, motion experience, head movements and other activities, the visual environment, odours and anti-motion sickness drugs. The precise importance of these factors is not yet sufficiently known for their effects to be quantified in this standard.

The guidance may be used for design purposes (e.g. considering overall ship performance or stabilizer requirements) or for operational purposes (e.g. considering the suitability of weather or the optimum locations of passengers and crew aboard ships). It should also aid the comparison of data obtained from continued research.

NOTE 1 Due to limitations in available data no guidance is given for the effects of x- or y-axis translational vibration or any axis of rotational vibration. However it is strongly recommended that measurements of motion should be obtained in these axes and fully reported since it is known that they can cause sickness.

NOTE 2 Although no guidance is given for the effects of rotational motions they will often have a large influence on the measured magnitude of z-axis motion. For example, pitch and roll oscillations of a ship cause vertical motions whose magnitudes vary with position in the ship. Measurements of translational motion are therefore usually only applicable to a small area over which there is little change in motion. Different magnitudes of vertical motion will probably occur in other locations and their effects may be different.

7.2 Motion evaluation guide

7.2.1 *Frequency weighting.* A single frequency weighting (W_f) is required for the evaluation of the effects of vibration on the incidence of motion sickness.

7.2.2 *Evaluation of simple and complex motion spectra.* In order to characterize the motions associated with sickness by a single quantity, the overall acceleration signal should be weighted and the true r.m.s. value of the frequency-weighted acceleration should be determined.

NOTE 1 It is strongly recommended that additional information about the motion conditions are also reported. This should include the frequency composition, durations and directions of motions.

NOTE 2 There is some evidence that motions having similar frequencies and r.m.s. accelerations but different waveforms may have different effects. This cannot be quantified in this standard.

7.2.3 *Motion in more than one direction.* The guidance given in clause **7** applies to vertical, z-axis motions only.

NOTE There is some evidence that roll and pitch motions of the body may also contribute to sickness symptoms. When sufficient data on the effects of other directions become available a summation procedure for all directions may be given.

7.2.4 *Motion of the head.* At low frequencies the translational motion of all parts of the body will tend to be similar. However, voluntary and involuntary rotational head movements will often occur. There is evidence that sickness may be reduced by reductions in rotational head motions. In practice this will usually be achieved by holding, or resting, the head against a structure moving with the seat (e.g. headrest).

7.2.5 *Motion with other postures.* The guidance given in clause **7** is only applicable to persons in sitting and standing postures. It is possible that the probability of sickness may be reduced in recumbent postures. It is not clear whether this arises because vertical motion is then in the x-axis of the body or because less rotational head motion occurs in this position.

7.2.6 *Evaluation of time-varying and repeated shock motions.* The crest factor of low frequency motions (i.e. after frequency weighting according to **7.2.1**) is not usually very great (up to about 8). In all cases, therefore, the r.m.s. magnitude of the motion should be determined by linear integration.

7.2.7 *Guide to effect of weighted motion magnitudes.* The procedures described in this standard encourage the uniform reporting of vibration conditions and allow meaningful comparisons of the relative severity of different environments. Vibration limits are not given.

NOTE Appendix D gives information on the interpretation of weighted motion magnitudes with respect to motion sickness and provides a relation between motion magnitude and exposure time.

Appendices

NOTE Appendix A to Appendix D should be considered as being for information only and not as part of the guide.

Appendix A Effects of vibration and repeated shock on health

A.1 General

This appendix indicates the current consensus on the relation between frequency-weighted vibration magnitudes, as described in clause **4** and health. It also provides a short bibliography relevant to clause **4**.

Since vibration conditions which may impair health will often have high crest factors it is necessary to define a procedure which is applicable to such motions. The preferred method, given in **A.3**, may be used with all types of vibration and repeated shock. The approximate method, given in **A.4**, may be used with low crest factor vibration.

A.2 Exposure duration

It may reasonably be assumed that increased exposure to vibration causes an increased risk of tissue damage and that periods of rest without vibration may lessen this risk. However there are no conclusive data showing how this risk is affected by exposure duration. In this appendix a time-dependency is defined as a relation between vibration magnitude and duration. The relation appears reasonable, it is consistent with current information and it is convenient for automated measurement procedures. The method involves the calculation of vibration dose values.

The preferred method of calculating vibration dose values has the additional advantages that it is not limited to low crest factor motions, and it may be applied to intermittent vibration exposures, to repeated shocks and also to those exposures consisting of periods of vibration at different magnitudes. An alternative method of estimating vibration dose values may be used with measurements of low crest factor motions measured as described in **4.2**.

A.3 Preferred method of vibration evaluation: calculation of vibration dose values

Where possible, the vibration dose value should be determined from a vibration measurement obtained throughout a 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.

$$\mathrm{VDV} = \left(\int_0^T a^4(t)\, \mathrm{d}t \right)^{1/4}$$

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.

When the vibration conditions are constant (or regularly repeated) throughout the day, only one representative period (of duration t_1) need be measured. The total vibration dose value for the day will then be given by the fourth root of the fourth power of the vibration dose value, VDV_1, (for the period t_1) after multiplication by t_0/t_1 (where t_0 is the total period of vibration exposure).

$$\mathrm{VDV} = \left(\frac{t_0}{t_1} \times \mathrm{VDV}_1^{\,4} \right)^{1/4}$$

In general, if in a day there is a total of N periods of various durations with measured (or estimated) vibration dose values, VDV_n, then the total vibration dose value for the day is the fourth root of the sun of the fourth powers of the individual vibration dose values.

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

NOTE 1 The procedure for calculating vibration dose values incorporates all time-dependencies currently considered necessary.

NOTE 2 The power of 4.0 is used in the calculation of vibration dose values because it gives a time-dependent assessment of the vibration magnitude which is consistent with current knowledge from exposure durations of the order of one cycle of motion to those of many hours. It is generally accepted that peak values may be particularly important with regard to damage to biological tissues: the use of the fourth power therefore gives a more realistic quantification than the second power as used in the calculation of r.m.s. values.

A.4 Alternative method of estimating vibration dose values

The root mean square values of short periods of the frequency-weighted acceleration may be used to estimate the vibration dose value when the crest factor is below 6.0 and a full day's exposure is comprised of periods of nearly constant r.m.s. magnitude.

The total vibration dose value for the day is approximated by the fourth root of the fourth power of 1.4 times the measured weighted r.m.s. value multiplied by the total duration, t_0 (in s), of vibration exposure.

$$\text{eVDV} = [(1.4 \times a)^4 \times b]^{1/4}$$

where:

eVDV is the estimated vibration dose value;

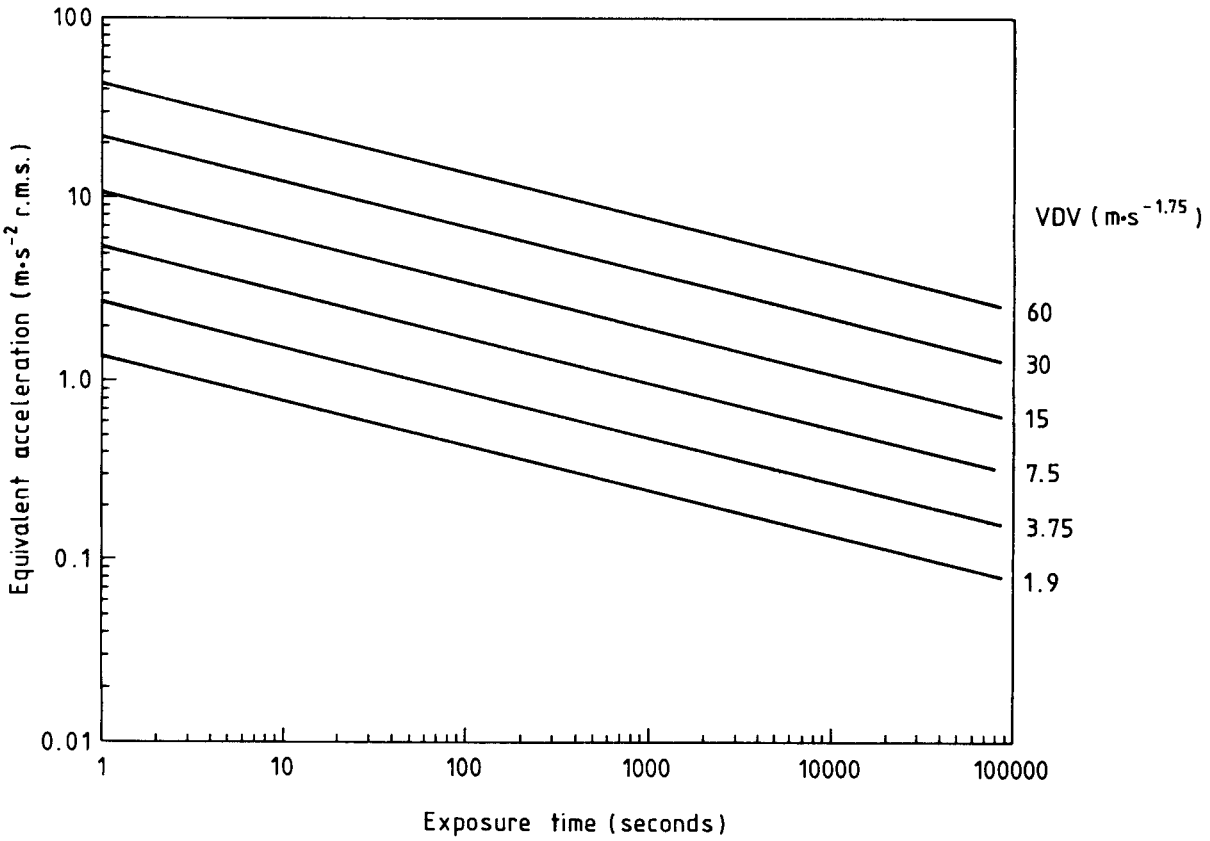
a is the r.m.s. value (in m·s^{-2});

b is the duration (in s).

The root-mean-square accelerations corresponding to various vibration dose values and exposure durations are shown in Figure 3.

NOTE 1 This procedure will underestimate the true vibration dose value when the crest factor exceeds about 6.0. 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 and estimated vibration dose values the procedures in **A.3** should be followed.



NOTE Vibration dose values employ a correction factor of 1.4. See **A.4**.

Figure 3 — Root-mean-square acceleration magnitudes corresponding to vibration dose values from 1.9 m·s$^{-1.75}$ to 60 m·s$^{-1.75}$ for vibration exposure periods from 1 s to 24 h

A.5 Multiaxis vibration

The severity of a vertical (z-axis) vibration exposure can be increased by the addition of sufficient horizontal vibration. The fourth root of the sum of the fourth powers of the vibration dose values in each axis should be determined to give the total vibration dose value for the environment.

NOTE Since vibration dose values depend on the fourth power of the acceleration magnitude this summation will only significantly increase the total vibration dose value when the weighted vibration magnitudes are very similar in two or more axes.

A.6 Guide to effect of vibration dose values

Sufficiently high vibration dose values will cause severe discomfort, pain and injury. Vibration dose values also indicate, in a general way, the severity of the vibration exposures which caused them. However, there is currently no consensus of opinion on the precise relation between vibration dose values and the risk of injury. It is known that vibration magnitudes and durations which produce vibration dose values in the region of 15 m·s$^{-1.75}$ will usually cause severe discomfort. It is reasonable to assume that increased exposure to vibration will be accompanied by increased risk of injury.

At high vibration dose values prior consideration of the fitness of the exposed persons and the design of adequate safety precautions may be required. The need for regular checks on the health of routinely exposed persons may also be considered.

NOTE 1 Using a correction factor of 1.4, as in **A.4**, the 5 Hz to 8 Hz vibration magnitude corresponding to a vibration dose value of 15 m·s$^{-1.75}$ may be considered similar to the "exposure limit" for 4 h given in ISO 2631:1985. For periods less than about 4 h the present guidance provides values below the "exposure limit". The magnitudes are above the "exposure limit" for periods greater than about 4 h. However a precise comparison with ISO 2631:1985 must take into account the methods for assessing multiple frequencies, multiple axis and intermittent vibration. The magnitude of the influence of these factors will vary between situations.

NOTE 2 The weighting used for x- and y-axis vibration can allow high magnitudes of high frequency acceleration. High magnitudes of such frequencies are not often encountered and are not greatly transmitted through the body. However it is possible that local effects of this type of motion may occur at magnitudes lower than those required to impair the health of the whole-body.

NOTE 3 With short duration low frequency vibration the peak acceleration magnitude may exceed $1g_n$. In these circumstances there may be an additional hazard with the person lifting off the seat and subsequently impacting with the seat. Appropriate physical restraints are required to prevent the separation of the body from the seat.

A.7 Bibliography

ALLEN, G. R. (1977) Human tolerance of repeated shocks. *Proceedings of the European Symposium on Life Sciences Research in Space.* ESA Report SP-130, 343–349.

DAMKOT, D.K., POPE, M.H., LORD, J. AND FRYMOYER, J.W. (1984) The relationship between work history, work environment and low back pain in men. *Spine,* **9** (4), 395–399.

DUPUIS, H. and CHRIST, W. (1972) Untersuchung der Moglichteit yon Gesundheitsschadigungen in Bereich der Wirbelsaule bei Schlepperfahrern (Zweite Folgeunter-suchung). *Arb.a.d. Max-Planck Inst. f. Landarbeit und Landtechnik, B. Kreuznach.* A72/2.

DUPUIS, H. and ZERLETT, G. (1984) Beanspruchung des Menschen durch mechanische Swingungen. *Schriftenreihe des Hauptverbandes der gewerblichen Berufsgenossen-schaften e. V.* ISBN 3-88383-107-7.

GRIFFIN, M.J. (1982) The effects of vibration on health. Report prepared for the Health and Safety Directorate of the Commission of the European Communities. ISVR Memorandum No. 632.

GRIFFIN, M.J. (1986) Evaluation of vibration with respect to human response. Paper presented to Annual Congress of Society of Automotive Engineers, Detroit, February. SAE paper 860047.

GRUBER, G.J. (1976) Relationships between whole-body vibration morbidity patterns among interstate truck drivers. DHEW (NIOSH) Publication No. 77–167.

GRUBER, G.J. and ZIPERMAN, H.H. (1974) Relationship between whole-body vibration and morbidity patterns among motor coach operators. HEW Publication No. (NIOSH) 751–104, Cincinnati, Ohio.

HEIDE, R. and SEIDEL, H. (1978) Folgen langzeitigen beruflicher Ganzkorpervibrationsexposition. *Zeitscherift fur die gesamte Hygiene und ihre Grenzgebiete,* **24**, 153–59.

KELSEY, J.L., GITHENS, P.B., O'CONNER, T., WEIL, U., CALOGERA, J.A., HOLFORD, T.R., WHITE, A.A., WALTER, S.D., OSTFELD, A.M. and SOUTHWICK, W.O. (1984) Acute prolapsed lumbar intervertebral disc. An epidemiologic study with special reference to driving automobiles and cigarette smoking. *Spine,* **9** (6), 608–613.

KELSEY, J.L. and HARDY, R.J. (1975) Driving of motor vehicles as a risk factor for acute herniated lumbar intervertebral disc. *American Journal of Epidemiology,* 102, 63–73.

KJELLBERG, A. and WIKSTROM, B-O (1985) Whole-body vibration: exposure time and acute effects — a review. *Ergonomics,* **28** (3), 535–544.

MILBY, T.H. and SPEAR, R.C. (1974) Relationship between whole-body vibration and morbidity patterns among heavy equipment operators. HEW Publication No. (NIOSH) 74–131, Cincinnati, Ohio.

ROSEGGER, R. and ROSEGGER, S. (1960) Health effects of tractor driving. *Journal of Agricultural Engineering Research,* **5** (3), 241–275.

SANDOVER, J. (1983) Dynamic loading as a possible source of low-back disorders. *Spine,* **8** (6).

SPEAR, R.C., KELLER, C., BEHRENS, V., HUDE, M. and TARTER, D. (1976) Morbidity patterns among heavy equipment operators exposed to whole-body vibration — 1975. DHEW Pub: NIOSH 77/120.

Appendix B Effects of vibration on human activities

B.1 General

This appendix indicates the current consensus on the relation between frequency-weighted vibration magnitudes, described in clause **5**, and both hand control activities and human vision. It also provides a bibliography relevant to clause **5**.

B.2 Guide to effects of weighted vibration magnitudes

B.2.1 *Hand manipulation and control*

The procedure described in the standard allows the uniform reporting of the severity of vibration exposures in a manner relevant to the effects of vibration on hand manipulation. The likely relative effects of two different environments on performance may be assessed from the weighted vibration magnitudes.

For precise information, detailed investigation will be necessary. However, it may often be found that where hand (or finger) control is required to an accuracy of within 5 mm r.m.s. or 2.5 N r.m.s. the weighted acceleration magnitude in any axis should not exceed 0.5 $m \cdot s^{-2}$ r.m.s. If less accuracy is required the weighted values could be increased in linear proportion.

B.2.2 *Vision*

The likely relative effects of two different environments on vision may also be assessed from the weighted vibration magnitudes.

Precise guidance will require detailed investigation. However, it may often be found that where it is necessary to resolve **detail** which subtends less than 2 minutes of arc at the eye, the weighted acceleration magnitude should not exceed 0.5 $m \cdot s^{-2}$ r.m.s. For every increase by a factor of $\sqrt{2}$ in the size of the detail which is to be resolved the vibration magnitude could be doubled.

NOTE 1 The above guidance is based on studies with alphanumeric reading tasks and should cause less than 5 % increase in reading error rate. Percentage reading error may be assumed to have an approximately linear relationship with weighted vibration magnitudes above 0.5 $m \cdot s^{-2}$ r.m.s. and up to an approximately 50 % error. (The data apply where unfamiliar alphanumeric data are being read.) For alphanumeric characters the value of 2 minutes of arc refers to the angle subtended by lines and gaps in the character, not the larger angle subtended by the overall height of the character.

NOTE 2 The guidance assumes persons have normal vision (Snellen visual acuity 6/6 or better) and optimum contrast and illumination. If the contrast or illumination conditions are extreme, lower vibration magnitudes may be advisable.

B.3 Bibliography

ALLEN, R.W., JEX, H.R. and MAGDALENO, R.E. (1973) Manual performance and dynamic response during sinusoidal vibration. AMRL-TR-73-78.

DEAN, R.D., FARRELL, R.J. and HITT, J.D. (1969) Effect of vibration on the operation of decimal input devices. *Human Factors,* **11,** 257–271.

GRIFFIN, M.J. (1975) Levels of whole-body vibration affecting human vision. *Aviation Space Environmental Medicine,* **46** (8), 1033–1040.

GRIFFIN, M.J. and LEWIS, C.H. (1978) A review of the effects of vibration on visual acuity and continuous manual control. Part 1: Visual acuity. *Journal of Sound and Vibration,* **56** (3), 383–413.

GRIFFIN, M.J., McLEOD, R.W., MOSELEY, M.J. and LEWIS, C.H. (1986) Whole-body vibration and aircrew performance. ISVR Technical Report No. 132. The University, Southampton.

HOLLAND, C.L. (1967) Performance effects of long term random vertical vibration. *Human Factors,* **9**, 93–104.

HORNICK, R.J. (1962) The effects of whole-body vibration in three directions upon human performance. *Journal of Engineering Psychology,* **1,** 93–101.

LEVISON, W.H. (1976) Biomechanical response and manual tracking performance in sinusoidal, sum of sines and random vibration environments. AMRL-TR-75-94.

LEVISON, W.H. (1976) Biomechanical and performance response of man in six different directional axis vibration environments. AMRL-TR-77-71.

LEVISON, W.H. and HOUCK, P. (1975) A guide for the design of control sticks in vibration environments. AMRL-TR-74-127.

LEWIS, C.H. and GRIFFIN, M.J. (1978) A review of the effects of vibration on visual acuity and continuous manual control. Part II: Continuous manual control. *Journal of Sound and Vibration,* **56** (3), 415–457.

LEWIS, C.H. and GRIFFIN, M.J. (1978) Predicting the effects of dual-frequency vertical vibration on manual control performance. *Ergonomics,* **21** (8), 637–650.

McLEOD, R.W. and GRIFFIN, M.J. (1986) A design guide for visual displays and manual tasks in vibration environments. Part 2 Manual Tasks. ISVR Technical Report No 134. The University, Southampton.

MEDDICK, R.D.L. and GRIFFIN, M.J. (1976) The effect of two-axis vibration on the legibility of reading material. *Ergonomics,* **19,** 21–33.

MOSELEY, M.J., LEWIS, C.H. and GRIFFIN, M.J. (1982) Sinusoidal and random whole-body vibration: comparative effects on visual performance. *Aviation Space Environmental Medicine,* **53** (10), 1000–1005.

MOSELEY, M.J. and GRIFFIN, M.J. (1986) A design guide for visual displays and manual tasks in vibration environments. Part 1 Visual Displays. ISVR Technical Report No. 133. The University, Southampton.

SHOENBERGER, R.W. (1970) Human Performance as a function of direction and frequency of whole-body vibration. AMRL-TR-70-71.

TORLE, G. (1965) Tracking performance under random acceleration: effects of control dynamics. *Ergonomics,* **8**, 481–486.

Appendix C Effects of vibration and repeated shock on comfort and perception

C.1 General

This appendix indicates the current consensus on the relation between frequency-weighted vibration magnitudes, as described in clause **6**, and human comfort. Perception thresholds for whole-body vibration are also defined and a bibliography relevant to clause **6** is provided.

C.2 Guide to effects of weighted vibration magnitudes

C.2.1 *Comfort*

C.2.1.1 *Environmental context.* A particular vibration condition may be considered to cause unacceptable discomfort in one situation but be classed as pleasant or exhilarating in another. Many factors combine to determine the degree to which discomfort may be noticed or tolerated. The standard is solely concerned with providing a uniform and convenient method of indicating the subjective severity of the vibration. An accurate assessment of the acceptability of the vibration, and the formulation of vibration limits, can only be made in the knowledge of many other factors.

Interference with activities (e.g. writing and drinking) due to vibration may sometimes be considered a cause of discomfort. These effects are often highly dependent on the detail of the activity (e.g. support used for writing and cup used for drinking) but some general guidance will be found in clause **5**.

C.2.1.2 *High crest factor and intermittent vibration.* When crest factors exceed approximately 6.0, the r.m.s. procedures given in the standard will underestimate the discomfort produced by the vibration. For these situations, the root-mean-quad value will be more likely to predict accurately the relative discomfort of motions of similar duration than the r.m.s. value.

$$\text{r.m.q.} = \left(\frac{1}{T}\int a^4(t)\,\mathrm{d}t\right)^{1/4}$$

If vibration exposures consist of periods of high and low vibration throughout variable periods of time, the vibration dose value may be determined as described in Appendix A. This procedure makes it possible to estimate the relative discomfort produced by two events of different durations: the event (or environment) giving the higher vibration dose value will also usually cause the greater discomfort.

NOTE The frequency weightings used in clause **4** and Appendix A are the same as those used for the same axes in clause **6** and in this Appendix (C).

C.2.1.3 *Possible reactions to vibration magnitudes.* The two principal purposes of frequency-weighted vibration magnitudes are:

a) the provision of a defined objective method of comparing the discomfort due to vibration in different situations; and

b) the provision of a unit which may be used to set specifications for particular systems.

The limiting acceptable values will depend on many factors which vary with each application. It is therefore not desirable to define a limit in this standard. The following values give very approximate indications of the likely reactions to various magnitudes of frequency-weighted r.m.s. acceleration:

< 0.315 m s^{-2}	not uncomfortable
$0.315 - 0.63$ m s^{-2}	a little uncomfortable
$0.5 - 1.0$ m s^{-2}	fairly uncomfortable
$0.8 - 1.6$ m s^{-2}	uncomfortable
$1.25 - 2.5$ m s^{-2}	very uncomfortable
> 2.0 m s^{-2}	extremely uncomfortable

NOTE It is important to recognize that acceptable conditions in one environment may be unacceptable in others.

C.2.2 ***Perception***

Fifty percent of alert fit persons can just detect a weighted vibration with a peak magnitude of approximately 0.015 m s^{-2}.

There is a large variation between individuals in their ability to perceive vibration. For a median perception threshold of approximately 0.015 m s^{-2} the interquartile range of responses may extend from about 0.01 m s^{-2} to 0.02 m s^{-2} peak.

C.3 Bibliography

ALLEN, G.R. (1975) Ride quality and International Standard ISO 2631.
NASA TM X-3295/DOT-TSC-OST-75-40.

ASHLEY, C. (1970) Equal annoyance contours for the effects of sinusoidal vibration on man. *Shock and Vibration Bulletin,* **41** (2), 13–20.

BENSON, A.J. and DILNOT, S. (1981) Perception of whole-body linear oscillation. U.K. Informal Group Meeting on Human Response to Vibration, Heriot-Watt University, Edinburgh, 9-11th September.

CORBRIDGE, C. and GRIFFIN, M.J. (1986) Vibration and comfort: vertical and lateral motion in the range 0.5 to 5.0 Hz. *Ergonomics,* **29** (2), 249–272.

DEMPSEY, T.K., LEATHERWOOD, J.D. and CLEVENSON, S.A. (1979) Discomfort criteria for single-axis vibrations. NASA Technical Paper 1422.

FOTHERGILL, L.C. and GRIFFIN, M.J. (1977) Evaluation of discomfort produced by multiple frequency whole-body vibration. *Ergonomics,* **20** (3), 263–276.

GIBSON, P.D.G. and OLIVER, R.J. (1978) The sensitivity of supine stretcher-borne human subjects to vibration in three translational and two rotational modes. MIRA Report No. K13010.

GRIFFIN, M.J. (1976) Subjective equivalence of sinusoidal and random whole-body vibration. *Journal of the Acoustical Society of America,* **60** (5), 1140–1145.

GRIFFIN, M.J. (1986) Evaluation of vibration with respect to human response. Paper presented to Annual Congress of Society of Automotive Engineers, Detroit, February, SAE paper 860047.

GRIFFIN, M.J. and WHITHAM, E.M. (1977) Assessing the discomfort of dual-axis whole-body vibration. *Journal of Sound and Vibration,* **54** (1), 107–116.

GRIFFIN, M.J. and WHITHAM, E.M. (1980a) Discomfort produced by impulsive whole-body vibration. *Journal of the Acoustical Society of America,* **68**, 1522–1523.

GRIFFIN, M.J., PARSONS, K.C. and WHITHAM, E.M. (1982) Vibration and comfort: IV Application of experimental results. *Ergonomics,* **25** (8), 721–739.

GUNDRY, A.J. (1978) Thresholds of perception for periodic linear motion. *Aviation Space and Environmental Medicine,* **49** (5), 679–686.

JONES, A.J. and SAUNDERS, D.J. (1974) A scale of human reacton to whole-body vertical, sinusoidal vibration. *Journal of Sound and Vibration,* **35**, 503–520.

KJELLBERG, A., WIKSTROM, B-O and DIMBERG, U. (1985) Whole-body vibration: exposure time and acute effects — experimental assessment of discomfort. *Ergonomics,* **28** (3), 545–554.

MIWA, T. (1967) Evaluation methods for vibration effect. 1. Measurements of thresholds and equal sensation contours of whole-body for vertical and horizontal vibrations. *Industrial Health,* **5,** 183–205.

MIWA, T. and YONEKAWA, Y. (1969) Evaluation methods for vibration effect. Part 9. *Response to sinusoidal vibration at lying posture. Industrial Health,* **7**, 116–126.

OBORNE, D.J. (1978) The stability of equal sensation contours of whole-body vibration. *Ergonomics,* **21,** 651–658.

PARSONS, K.C. and GRIFFIN, M.J. (1978) The effect of the position of the axis of rotation on the discomfort caused by whole-body roll and pitch vibrations of seated persons. *Journal of Sound and Vibration,* **58** (1), 127–141.

PARSONS, K.C. and GRIFFIN, M.J. (1987) Whole-body vibration perception thresholds. (Awaiting publication in *Journal of Sound and Vibration.*)

SHOENBERGER, R.W. (1976) Comparison of the subjective intensity of sinusoidal, multi-frequency and random whole-body vibration. *Aviation Space and Environmental Medicine,* **47** (8), 856–862.

Appendix D Effects of whole-body low frequency vibration on the incidence of motion sickness

D.1 General

This appendix indicates the current consensus on the relation between frequency-weighted vibration magnitudes, as described in clause **7**, and the incidence of sickness. A bibliography relevant to clause **7** is also provided.

D.2 Duration (exposure time) of vibration

The probability of occurrence of sickness symptoms increases with increasing duration of motion exposure up to several hours. Over longer periods (a few hours to a few days) adaptation to the motion occurs. Some adaptation (i.e. lowered sensitivity) may be retained so as to reduce the probability of sickness due to similar motions on a future occasion.

A motion sickness dose value is defined such that higher values correspond to a greater incidence of sickness.

There are two alternative methods of calculating the motion sickness dose value.

a) Where possible, the motion sickness dose value should be determined from motion measurements throughout the full period of exposure. The motion sickness dose value is given by the square root of the integral of the square of the z-axis acceleration after it has been frequency weighted.

$$MSDV_z = \left(\int_0^T a^2(t)\, dt \right)^{1/2}$$

where:

$MSDV_z$ is the motion sickness value (in m $s^{-1.5}$);

a (t) is the frequency-weighted acceleration;

T is the total period (in s) during which motion could occur.

This method is equivalent to calculating the r.m.s. value by true integration over the period *T* and multiplying by $T^{1/2}$.

b) If the motion exposure is continuous and of approximately constant magnitude, the motion sickness dose value may be estimated from the frequency-weighted r.m.s. value determined over a short period. The motion sickness dose value, $MSDV_z$, for the exposure period, t_0 s, is found by multiplying the square of the measured r.m.s. value, *a*, by the exposure period, t_0, and taking the square root.

$MSDV_z = (a^2\, t_0)^{1/2}$

NOTE When using method b) above, the measurement period should not normally be less than 240 s.

D.3 Guide to the effect of motion sickness dose values

There are large differences in the susceptibility of individuals to the effects of low frequency oscillation. It has been found that females are more prone to motion sickness than males and that the prevalence of symptoms declines with increasing age.

Laboratory experimental studies and data from mixed groups of passengers on ships suggests that the percentage of unadapted adults who are likely to vomit may be approximated by:

percentage of persons who may vomit = $K_m \times MSDV_z$

where K_m is a constant which may vary according to the exposed population but, for a mixed population of unadapted male and female adults K_m = 1/3. These relationships are based on exposures to motion lasting from about 20 min to about 6 h with the prevalence of vomiting varying up to about 70 %.

D.4 Bibliography

ALEXANDER, S.J., COTZIN, M., KLEE, J.B., WENDT, G.R. (1947) Studies of motion sickness: XVI. The effects upon sickness rates of waves of various frequencies but identical acceleration. *Journal of Experimental Psychology,* **37**, 440–448.

ALLEN, G.R. (1975) Proposed limits for exposure to whole-body vertical vibration, 0.1 to 1.0 Hz. AGARD-CP 145.

BENSON, A.J. (1984) Motion sickness. In: *Vertigo,* edited by M. R. Dix and J.D. Hood. Published by John Wiley and Sons, 391–426.

GUIGNARD, J.C. and McCAULEY, M.E. (1982) Motion sickness incidence induced by complex periodic wave-forms. *Aviation Space and Environmental Medicine,* **53** (6), 554–563.

LAWTHER, A. and GRIFFIN, M.J. (1981) Measurement of ship motion. In: *Human Factors in Transport Research.* Volume 2. Eds. Oborne, D.J., and Levis, J.A. Published by Academic Press, 131–139.

LAWTHER, A. and GRIFFIN, M.J. (1986) The motion of a ship at sea and the consequent motion sickness amongst passengers. *Ergonomics,* **29** (4), 535–552.

LAWTHER, A. and GRIFFIN, M.J. (1986) Prediction of the incidence of motion sickness from the magnitude, frequency and duration of vertical oscillation. (Awaiting publication in the Journal of the Acoustical Society of America.)

LAWTHER, A. and GRIFFIN, M.J. (1987) The relation of motion sickness amongst passengers to the motion characteristics of vessels at sea. (In preparation.)

MONEY, K. E. (1970) Motion sickness. *Physiological Review,* **50**, 1–39.

O'HANLON, J. F. and McCAULEY, M.E. (1974) Motion sickness incidence as a function of the frequency and acceleration of vertical sinusoidal motion. *Aerospace Medicine,* **45** (4), 366–369.

REASON, J.T. and BRAND, J.J. (1975) Motion sickness. Published by Academic Press.

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Publications referred to

BS 6472, *Guide to the evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz).*
ISO 2041, *Vibration and shock — Vocabulary.*
ISO 2631, *Guide for the evaluation of human exposure to whole-body vibration.*
ISO 5805, *Mechanical vibration and shock affecting man — Vocabulary.*
ISO 8041, *Human-response vibration measuring instrumentation*[2)].
SAE J1013, *Measurement of whole body vibration of the seated operator of agricultural equipment.*
SAE 770253, *Measuring vibration on soft seats.*

[2)] In preparation.

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