
AMERICAN NATIONAL STANDARD

Mechanical vibration and shock—Evaluation of human exposure to whole-body vibration—Part 1: General requirements

(A Nationally Adopted International Standard)

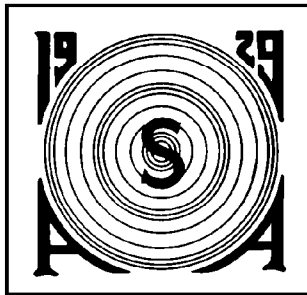
NAIS STANDARD
ANSI S3.18-2002
ISO 2631-1:1997

Accredited Standards Committee S3, Bioacoustics

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114E
Melville, NY 11747-3177

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to whole-body vibration — Part 1:
General requirements**

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Secretariat

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Approved 13 May 2002

American National Standards Institute, Inc.

Abstract

This part of ISO 2631 defines methods for the measurement of periodic, random and transient whole-body vibration. It indicates the principal factors that combine to determine the degree to which a vibration exposure will be acceptable. Informative annexes indicate current opinion and provide guidance on the possible effects of vibration on health, comfort and perception and motion sickness. The frequency range considered is

- 0.5 Hz to 80 Hz for health, comfort and perception and
- 0.1 Hz to 0.5 Hz for motion sickness.

Although the potential effects on human performance are not covered, most of the guidance on whole-body vibration measurement also applies to this area. This part of ISO 2631 also defines the principles of preferred methods of mounting transducers for determining human exposure. It does not apply to the evaluation of extreme-magnitude single shocks such as occur in vehicle accidents.

This part of ISO 2631 is applicable to motions transmitted to the human 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. This type of vibration is found in vehicles, in machinery, in buildings and in the vicinity of working machinery.

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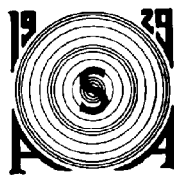
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Foreword

[This foreword is not part of the Nationally Adopted International Standard (NAIS), Mechanical vibration and shock – Evaluation of human exposure to whole body vibration – Part 1: General requirements, ANSI S3.18-2002, ISO 2631-1:1997.]

This Nationally Adopted International Standard (NAIS) comprises a part of a group of definitions, standards, and specifications for use in acoustical work. It has been adopted by the American National Standards Institute utilizing the Accredited Standards Committee Procedures, under the Secretariat of the Acoustical Society of America.

Accredited Standards Committee S3, Bioacoustics, under whose jurisdiction this NAIS Standard was adopted, has the following scope:

Standards, specifications, methods of measurement and test, and terminology in the fields of psychological and physiological acoustics, including aspects of general acoustics, shock, and vibration which pertain to biological safety, tolerance and comfort.

This Standard is identical to International Standard ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole body vibration, which was prepared by Technical Committee ISO/TC 108, Mechanical vibration and shock, Subcommittee SC 4, Human exposure to Mechanical vibration and shock.

At the time this NAIS Standard was submitted to Accredited Standards Committee S3, Bioacoustics, for final approval, the membership was as follows:

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Suggestions for improvement of this Standard will be welcomed. They should be made in writing to Accredited Standards Committee S3, Bioacoustics, in care of the Standards Secretariat, Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177.

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Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration —

Part 1: General requirements

1 Scope

This part of ISO 2631 defines methods for the measurement of periodic, random and transient whole-body vibration. It indicates the principal factors that combine to determine the degree to which a vibration exposure will be acceptable. Informative annexes indicate current opinion and provide guidance on the possible effects of vibration on health, comfort and perception and motion sickness. The frequency range considered is

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2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 2631. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 2631 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 5805:1997, *Mechanical vibration and shock — Human exposure — Vocabulary*.

ISO 8041:1990, *Human response to vibration — Measuring instrumentation*.

IEC 1260:1995, *Electroacoustics — Octave-band and fractional-octave-band filters*.

3 Definitions

For the purposes of this part of ISO 2631, the terms and definitions given in ISO 2041 and ISO 5805 apply.

4 Symbols and subscripts

4.1 Symbols

- a Vibration acceleration. Translational acceleration is expressed in metres per second squared (m/s^2) and rotational acceleration is expressed in radians per second squared (rad/s^2). Values are quoted as root-mean-square (r.m.s) unless stated otherwise
- $H(p)$ Transfer function, or gain, of a filter expressed as a function of the imaginary angular frequency (complex frequency)
- $p = j 2 \pi f$ Imaginary angular frequency
- w Frequency weighting

4.2 Subscripts

- c, d, e, f, j, k Refer to the various frequency-weighting curves recommended for evaluation with respect to health, comfort, perception and motion sickness (see tables 1 and 2).
- w Refers to frequency-weighted acceleration values.
- x, y, z Refer to the direction of translational, or rectilinear, vibration (see figure 1).
For rotational vibration, they refer to the axis of rotation, r . (Rotation about x -, y - and z -axes is designated roll, pitch and yaw, respectively, see figure 1.)
- v Refers to the vector sum of the overall weighted acceleration in the x -, y - and z -axes.

Table 1 — Guide for the application of frequency-weighting curves for principal weightings

Frequency weighting	Health (see clause 7)	Comfort (see clause 8)	Perception (see clause 8)	Motion sickness (see clause 9)
W_k	z -axis, seat surface	z -axis, seat surface z -axis, standing vertical recumbent (except head) x -, y -, z -axes, feet (sitting)	z -axis, seat surface z -axis, standing vertical recumbent (except head)	—
W_d	x -axis, seat surface y -axis, seat surface	x -axis, seat surface y -axis, seat surface x -, y -axes, standing horizontal recumbent y -, z -axes, seat-back	x -axis, seat surface y -axis, seat surface x -, y -axes, standing horizontal recumbent	—
W_i	—	—	—	vertical

Table 2 — Guide for the application of frequency-weighting curves for additional weighting factors

Frequency weighting	Health (see clause 7)	Comfort (see clause 8)	Perception (see clause 8)	Motion sickness (see clause 9)
W_c	x -axis, seat-back ¹⁾	x -axis, seat-back	x -axis, seat-back	—
W_o	—	r_x -, r_y -, r_z -axes, seat surface	r_x -, r_y -, r_z -axes, seat surface	—
W_j	—	vertical recumbent (head) ²⁾	vertical recumbent (head) ²⁾	—
1) See note in subclause 7.2.3.				
2) See note in subclause 8.2.2.3.				

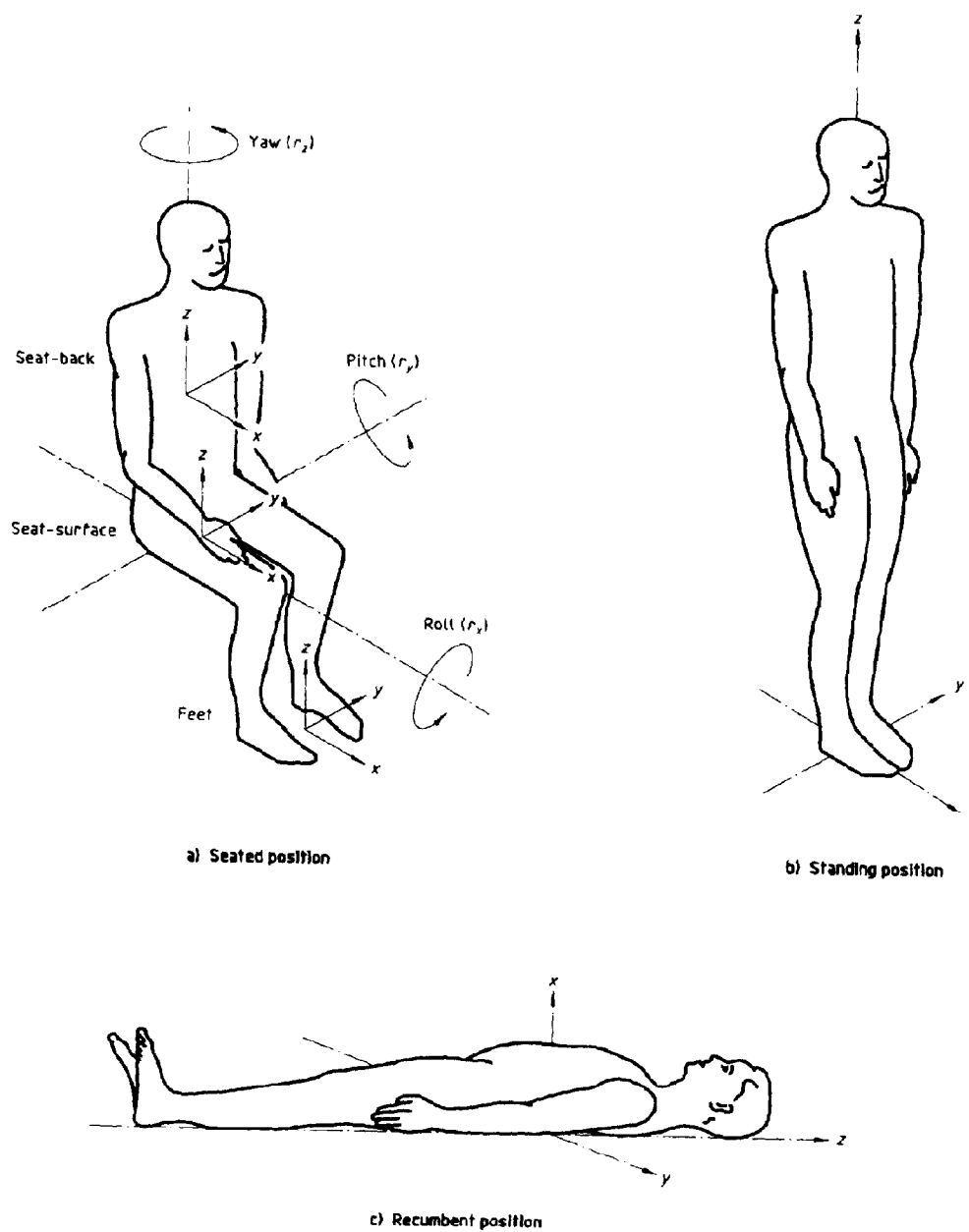


Figure 1 — Basicentric axes of the human body

5 Vibration measurement

5.1 General

The primary quantity of vibration magnitude shall be acceleration (see 4.1).

In case of very low frequencies and low vibration magnitudes, e.g. in buildings or ships, velocity measurements may be made and translated into accelerations.

5.2 Direction of measurement

5.2.1 Vibration shall be measured according to a coordinate system originating at a point from which vibration is considered to enter the human body. The principal relevant basicentric coordinate systems are shown in figure 1.

5.2.2 If it is not feasible to obtain precise alignment of the vibration transducers with the preferred basicentric axes, the sensitive axes of transducers may deviate from the preferred axes by up to 15° where necessary. For a person seated on an inclined seat, the relevant orientation should be determined by the axes of the body, and the z-axis will not necessarily be vertical. The orientation of the basicentric axes to the gravitational field should be noted.

5.2.3 Transducers located at one measurement location shall be positioned orthogonally. Translational accelerometers orientated in different axes at a single measurement location shall be as close together as possible.

5.3 Location of measurement

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

Vibration which is transmitted to the body shall be measured on the surface between the body and that surface.

The principal areas of contact between the body and a vibrating surface may not always be self-evident. This part of ISO 2631 uses 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 in the area of principal support of the body. Measurements at the feet should be made on the surface on which the feet are most often supported. For recumbent positions, this part of ISO 2631 considers the supporting surface to be under the pelvis, the back and the head. In all cases the location of measurement shall be fully reported.

NOTES

1 Where direct measurements are not practicable, vibration may be measured at a rigid portion of the vehicle or building structure such as the centre of rotation or the centre of gravity. The evaluation of such data in terms of human response requires additional calculations and requires knowledge about the structural dynamics of the system being evaluated.

2 Measurements at the seat-back are preferably made at the interface with the body. Where this is difficult, measurements may be made on the frame of the seat behind the backrest cushion. If measurements are made at this position they are to be corrected for the transmissibility of the cushion material.

3 Vibration which is transmitted to the body from rigid surfaces may be measured on the supporting surface closely adjacent to the area of contact between the body and that surface (usually within 10 cm of the centre of this area).

5.3.2 Vibration which is transmitted to the body from a non-rigid or resilient material (e.g. the seat cushion or couch) shall be measured with the transducer interposed between the person and the principal contact areas of the surface. This should be achieved by securing the transducers within a suitably formed mount. The mount shall not greatly alter the pressure distribution on the surface of the resilient material. For measurements on non-rigid surfaces, a person shall adopt the normal position for the environment.

NOTE — A commonly used design for accelerometer mount for seat vibration measurements is given in ISO 10326-1.

5.4 General requirements for signal conditioning

The vibration evaluation procedures defined in this part of ISO 2631 incorporate methods of averaging vibration over time and over frequency bands. The frequency response of the vibration transducer and associated signal conditioning prior to signal processing shall be appropriate to the range of frequencies specified in the relevant clauses of this part of ISO 2631.

The dynamic range of the signal-conditioning equipment shall be adequate for the highest and lowest signals. Signals to be recorded for later analysis may first be passed through a low-pass filter having a cutoff (-3 dB) frequency of approximately 1,5 times the highest frequency of interest in order to maximize the signal-to-noise ratio and the phase characteristic shall be linear within the range of frequencies specified in the relevant clauses of this part of ISO 2631.

5.5 Duration of measurement

The duration of measurement shall be sufficient to ensure reasonable statistical precision and to ensure that the vibration is typical of the exposures which are being assessed. The duration of measurement shall be reported.

Where complete exposure consists of various periods of different characteristics, separate analysis of the various periods may be required.

NOTE — For stationary random signals, the measurement accuracy depends on the filter bandwidth and measurement duration. For example, to obtain a measurement error of less than 3 dB at a confidence level of 90 % requires a minimum measurement duration of 108 s for a lower limiting frequency (LLF) of 1 Hz and 227 s for a LLF of 0,5 Hz, when the analysis is done with a one-third octave bandwidth. The measurement period is normally much longer, such that it is representative of the vibration exposure.

5.6 Reporting of vibration conditions

This part of ISO 2631 has been formulated to simplify and standardize the reporting, comparison and assessment of vibration conditions. Proper use of this standard should result in clear documentation of results. This will involve a reference to the appropriate clauses and annexes of this part of ISO 2631 and to one or more of the frequency weightings.

Where alternative methods are described in this part of ISO 2631 it is important that the methods used are clearly reported.

Users of this part of ISO 2631 are encouraged to report both the magnitude and duration of any vibration exposure being assessed. If additional evaluation methods are applied according to 6.3 (e.g. when the crest factor is greater than 9) both the basic value and the additional value shall be reported. If the crest factor is determined, the time period of its measurement should be reported.

The specification of the severity of complex vibration conditions by one, or a few, values is convenient and often essential. However, it is desirable that more detailed information on vibration conditions become available. Reports should include information on the frequency content (i.e. vibration spectra), vibration axes, how conditions change over time, and any other factors which may influence the effect.

NOTE — Other factors may also affect human response to vibration: population type (age, gender, size, fitness, etc.); experience, expectation, arousal and motivation (e.g. difficulty of task to be performed); body posture; activities (e.g. driver or passenger); financial involvement.

6 Vibration evaluation

6.1 Basic evaluation method using weighted root-mean-square acceleration

The vibration evaluation according to this part of ISO 2631 shall always include measurements of the weighted root-mean-square (r.m.s.) acceleration, as defined in this subclause.

The weighted r.m.s. acceleration is expressed in metres per second squared (m/s²) for translational vibration and radians per second squared (rad/s²) for rotational vibration. The weighted r.m.s. acceleration shall be calculated in accordance with the following equation or its equivalents in the frequency domain

$$a_w = \left[\frac{1}{T} \int_0^T a_w^2(t) dt \right]^{\frac{1}{2}} \quad \dots (1)$$

where

$a_w(t)$ is the weighted acceleration (translational or rotational) as a function of time (time history), in metres per second squared (m/s²) or radians per second squared (rad/s²), respectively;

T is the duration of the measurement, in seconds.

Frequency-weighting curves recommended and/or used for the various directions and their applications are listed in tables 1 and 2 and discussed in the following subclauses and in annexes B, C and D. Numerical values of the weighting curves are given in tables 3 and 4 and exact definitions are given in annex A.

6.2 Applicability of the basic evaluation method

6.2.1 Definition of crest factor

For the purposes of this part of ISO 2631 the crest factor is defined as the modulus of the ratio of the maximum instantaneous peak value of the frequency-weighted acceleration signal to its r.m.s. value. The peak value shall be determined over the duration of measurement (see 5.5), i.e. the time period T used for the integration of the r.m.s. value (see 6.1).

NOTE — The crest factor does not necessarily indicate the severity of vibration (see 6.3).

6.2.2 Applicability of the basic evaluation method for vibration with high crest factors

The crest factor may be used to investigate if the basic evaluation method is suitable for describing the severity of the vibration in relation to its effects on human beings. For vibration with crest factors below or equal to 9, the basic evaluation method is normally sufficient. Subclause 6.3 defines methods applicable when the basic evaluation method is not sufficient.

NOTE — For certain types of vibrations, especially those containing occasional shocks, the basic evaluation method may underestimate the severity with respect to discomfort even when the crest factor is not greater than 9. In cases of doubt it is therefore recommended to use and report additional evaluations also for crest factors less than or equal to 9 according to 6.3. Subclause 6.3.3 indicates ratios between magnitudes evaluated by the additional methods and the basic method, above which it is recommended to use one of the additional methods, as a further basis for judgement of the influence on human beings.

6.3 Additional evaluation of vibration when the basic evaluation method is not sufficient

In cases where the basic evaluation method may underestimate the effects of vibration (high crest factors, occasional shocks, transient vibration), one of the alternative measures described below should also be determined — the running r.m.s. or the fourth power vibration dose value.

Table 3 — Principal frequency weightings in one-third octaves

Frequency band number ¹⁾ <i>x</i>	Frequency <i>f</i> Hz	<i>W_k</i>		<i>W_d</i>		<i>W_l</i>	
		factor × 1 000	dB	factor × 1 000	dB	factor × 1 000	dB
-17	0,02					24,2	-32,33
-16	0,025					37,7	-28,48
-15	0,031 5					59,7	-24,47
-14	0,04					97,1	-20,25
-13	0,05					157	-16,10
-12	0,063					267	-11,49
-11	0,08					461	-6,73
-10	0,1	31,2	-30,11	62,4	-24,09	695	-3,16
-9	0,125	48,6	-26,26	97,3	-20,24	895	-0,96
-8	0,16	79,0	-22,05	158	-16,01	1 006	0,05
-7	0,2	121	-18,33	243	-12,28	992	-0,07
-6	0,25	182	-14,81	365	-8,75	854	-1,37
-5	0,315	263	-11,60	530	-5,52	619	-4,17
-4	0,4	352	-9,07	713	-2,94	384	-8,31
-3	0,5	418	-7,57	853	-1,38	224	-13,00
-2	0,63	459	-6,77	944	-0,50	116	-18,69
-1	0,8	477	-6,43	992	-0,07	53,0	-25,51
0	1	482	-6,33	1 011	0,10	23,5	-32,57
1	1,25	484	-6,29	1 008	0,07	9,98	-40,02
2	1,6	494	-6,12	968	-0,28	3,77	-48,47
3	2	531	-5,49	890	-1,01	1,55	-56,19
4	2,5	631	-4,01	776	-2,20	0,64	-63,93
5	3,15	804	-1,90	642	-3,85	0,25	-71,96
6	4	967	-0,29	512	-5,82	0,097	-80,26
7	5	1 039	0,33	409	-7,76		
8	6,3	1 054	0,46	323	-9,81		
9	8	1 036	0,31	253	-11,93		
10	10	988	-0,10	212	-13,91		
11	12,5	902	-0,89	161	-15,87		
12	16	768	-2,28	125	-18,03		
13	20	636	-3,93	100	-19,99		
14	25	513	-5,80	80,0	-21,94		
15	31,5	405	-7,86	63,2	-23,98		
16	40	314	-10,05	49,4	-26,13		
17	50	246	-12,19	38,8	-28,22		
18	63	186	-14,61	29,5	-30,60		
19	80	132	-17,56	21,1	-33,53		
20	100	88,7	-21,04	14,1	-36,99		
21	125	54,0	-25,35	8,63	-41,28		
22	160	28,5	-30,91	4,55	-46,84		
23	200	15,2	-36,38	2,43	-52,30		
24	250	7,90	-42,04	1,26	-57,97		
25	315	3,98	-48,00	0,64	-63,92		
26	400	1,95	-54,20	0,31	-70,12		

1) Index *x* is the frequency band number according to IEC 1260.

NOTES

1 For tolerances of the frequency weightings, see 6.4.1.2.

2 If it has been established that the frequency range below 1 Hz is unimportant to the weighted acceleration value, a frequency range 1 Hz to 80 Hz is recommended.

3 The values have been calculated including frequency band limitation.