IS 14732 : 2000
ISO 6897 : 1984

भारतीय मानक

विशेषकर भवनों और तट से दूर स्थिर संरचनावों में रहने वालों की अल्प आवृति क्षैतिज गति (0.063 से 1 हर्टज) के प्रति अनुक्रिया के मूल्यांकन की मार्गदर्शिका

Indian Standard

GUIDELINES FOR THE EVALUATION OF THE RESPONSE OF OCCUPANTS OF FIXED STRUCTURES, ESPECIALLY BUILDINGS AND OFF-SHORE STRUCTURES, TO LOW-FREQUENCY HORIZONTAL MOTION (0.063 TO 1 HZ)

ICS 13.160

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

January 2000 **Price Group 4**

Mechanical Vibration and Shock Sectional Committee, LM 04

NATIONAL FOREWORD

This Indian Standard which is identical with ISO 6897:1984 'Guidelines for the evaluation of the response of occupants of fixed structures, especially buildings and off-shore structures, to low-frequency horizontal motion (0.063 to 1 Hz)' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of Mechanical Vibration and Shock Sectional Committee and approval of the Light Mechanical Engineering Division Council.

The text of ISO Standard has been approved as suitable for publication as Indian Standard without deviations. In the adopted standard certain conventions are not identical to those used in Indian Standards. Attention is especially drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a full point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 2631-1:1997	IS 13276 (Part 1): 2000 Evaluation of human exposure to whole body vibration : Part 1 General requirement (*first revision*)	Identical
ISO 2631-2:1989	IS 13276-2:1992 Evaluation of human exposure to whole body vibration : Part 2 Continuous and shock-induced vibration in buildings (1 to 50 Hz)	do

Indian Standard

GUIDELINES FOR THE EVALUATION OF THE RESPONSE OF OCCUPANTS OF FIXED STRUCTURES, ESPECIALLY BUILDINGS AND OFF-SHORE STRUCTURES, TO LOW-FREQUENCY HORIZONTAL MOTION (0.063 TO 1 HZ)

0 Introduction

Until this century, buildings were seldom more than a few storeys high and the few tall buildings which did exist were usually of a heavy gravity design which did not readily respond to wind or other forces. Also, tall buildings constructed in the late nineteenth century and early this century generally had vertical load-bearing frames with massive granite infills which provided another generation of unresponsive buildings.

This history of unresponsive building structures has led people to expect buildings to provide nearly stationary accommodation, even under storm conditions, and the occupants of buildings are prepared to accept only extremely low levels of motion.

In contrast to these unresponsive structures, more modern buildings have tended, for reasons of economy of space, foundation requirements, material outlay, speed of erection and elegance, to be formed from more slender sections such that these much lighter buildings are more responsive to dynamic forces than their predecessors. This International Standard proposes magnitudes of low-frequency horizontal motion that should produce only minimum adverse comment from people working or living in buildings.

Similarly, off-shore fixed structures were, until recently, generally of a non-habitable form or of an unresponsive design. Modern mineral exploitation and production structures founded on the seabed are of such large proportions and subject to such extreme wind and wave action that the dynamic response of both the overall structures and their component parts has become the focus of much attention from the viewpoint of the motion transmitted to those operating and living on the structures. Also, although outside the scope of this International Standard, the structural integrity, material fatigue and operation of off-shore fixed structures in storm conditions receive much attention. This International Standard therefore proposes magnitudes of low-frequency horizontal motion which should prove satisfactory to those living on and operating off-shore fixed structures. Allowances are made for the fact that wind and waves shall be expected to cause motion of these structures which, in addition, are generally manned by trained personnel who are prepared to accept some degree of motion so long as it does not present a health hazard or interfere with the efficient operation of the installation.

Often the likely motion of a planned structure has to be calculated in order to assess the probable response, to the vibration, of those who will use the structure. The probable motion of a proposed structure can generally be found by structural dynamics using the structure stiffness and mass, the wind or wind and wave spectra, the structure shape, aspect and roughness, and the appropriate topographical parameters. Wind tunnel and wave tank studies using aerodynamic and fluid dynamic models can also be used to determine the likely motion of structures.

In some forms of tall building construction, poor construction joints allow inter-storey drift in the structure and, when assessing the probable response of such structures, an allowance should be made for the effects of inter-storey movements.

Guidance on satisfactory magnitudes of vibration for specific situations is given in the annex.

1 Scope and field of application

1.1 This International Standard relates to typical responses of people to the horizontal motion of structures in the frequency range 0,063 to 1 Hz. The recommendations are categorized in accordance with the use of the structures and, in the case of off-shore fixed structures, with the nature of work being carried out.

Injury of occupants due to structural vibration is outside the scope of this International Standard.

1.2 Whole-body motion caused by structural vibrations induced by infrequent external environmental forces is considered separately from whole-body motion resulting from structural vibrations caused by frequently occurring force actions. Frequently occurring force actions may arise from external sources, machinery or structure services such as elevators, fans, air conditioners, heating units and plumbing. Both perceptible magnitudes of low-frequency horizontal motion of structures and magnitudes likely to raise minimum adverse comment are included.

NOTES

1 Visual perception of building motion, the influence of torsional oscillations of structures and the effects of noise may influence the subjective response to vibrations of structures but no quantitative assessment is made.

2 Blasting, earthquakes and similar events are excluded from the scope of this International Standard.

3 An off-shore fixed structure is one founded on the sea bed, such as a gravity platform or a steel jacket with a piled foundation. Floating structures, tension leg and articulated platforms are excluded from the scope of this International Standard.

4 In buildings, the response of people is for a normal adult population and, although it is known that levels of vibration considered acceptable vary with age groups and sex, no definite correction factors can be put forward at present to adjust the acceleration magnitudes for these influences. On off-shore fixed structures, the recommendations only apply to trained personnel.

5 This International Standard applies to horizontal motion of structures as perceived by human beings in any posture, sitting, standing or reclining.

2 References

ISO 2631/1, *Evaluation of human exposure to whole-body vibration — Part 1 : General requirements.*

ISO 2631/2, *Evaluation of human exposure to whole-body vibration — Part 2 : Evaluation of human exposure to vibration and shock in buildings (1 to 80 Hz).*[1)]

3 Response criteria

3.1 This International Standard considers three categories of human response to the vibration of structures :

a) basic threshold effects (see 3.5 and clause A.3);

b) intrusion, alarm and fear which may be associated with minor or major adverse comment levels (see 3.3, 3.4 and notes 1 and 2 in 3.6);

c) interference with activities (see 3.4, 3.5 and clause A.2).

3.2 The criterion for infrequently induced low-frequency horizontal building vibrations caused by storms is the alarm experienced by the occupants of the structure [category b) above]. The level of adverse comment due to such alarm is dependent upon the return period, the shorter the interval between occurrences the higher the level of adverse comment, and on the time over which motion of a particular intensity is sustained for each occurrence. The perception of motion is assumed to be sensed through proprioceptive cues or the vestibular organs rather than through visual cues. The presence of even very small torsional vibrations may greatly influence subjects in their assessment of the acceptability of the vibration of a structure (see A.1.3 and note 2 in A.3.2).

3.3 In buildings used for general purposes, the criterion is that probably not more than 2 % of those occupying the parts of the building where the motion is greatest comment adversely about the motion caused by the peak 10 min of the worst wind storm with a return period of 5 years or more. In regions where wind storm recurrence patterns are not well defined, a longer return period should be used. Present shortage of data prevents the definite stipulation of acceleration/frequency curves for storms with a return period of less than 5 years. Guidance on the expected level of adverse comment for such storms is currently limited to that given in note 3 in 3.6.

3.4 For off-shore fixed structures where non-routine or skilled manual operations are carried out, the criteria for infrequently induced low-frequency horizontal motion of such structures are related to the performance of those engaged in the operations (see clause A.2).

3.5 The criteria for regularly occurring horizontal building motions are related to the perception thresholds of horizontal motion for average and for sensitive humans, that is to the average and lower thresholds.

3.6 The criteria for regularly occurring horizontal motion of structures at frequencies greater than 1 Hz are given in ISO 2631 and associated documents.

NOTES

1 The buildings are assumed to be properly clad and acoustically insulated so that significant sounds caused by the wind and by building motions are minimized to the occupants. If this were not the case, the satisfactory magnitudes may be reduced since the effect of noise on the occupants is to influence the subjective response to the motion.

2 People long accustomed to living in some forms of low rise buildings, such as two-storey flexible wooden frame houses, are sometimes prepared to accept magnitudes of motion due to regularly recurring events, such as wind action or the passage of heavy vehicles, which cause alarm in occasional visitors. Conversely, occupants of high-rise buildings do not readily adapt to motions which cause them alarm on the first occurrence.

3 For a storm with a one-year return period which causes the magnitudes of motion recommended as satisfactory for a five-year return period, the adverse comment level from people occupying the parts of the building where motion is greatest is estimated to be 12 %. It is tentatively suggested that to obtain a probable adverse comment level of 2 % for storms with a one-year return period, the suggested satisfactory acceleration magnitudes would be 0,72 times those for a five-year return period.

4 In general, it may be assumed that the motions of duration less than 10 min associated with wind storms are not sufficiently severe to impress significantly the memory of individuals. Where the exposure period is shorter than 10 min, vibration amplitudes which are vividly remembered are generally a product of seismic activity.

5 During the peaks of wind storms, accelerations much in excess of the suggested satisfactory magnitudes will occur for short periods but these higher levels, briefly experienced, are not considered to make any great contribution to the memory of the storm except where momentary vibrations are in the extreme category mentioned in note 4. Short periods of higher acceleration which occur during the worst 10 consecutive minutes of the storm occurrence are accounted for in the r.m.s. value of the vibration of the structure for the storm peak (see note 1 in 4.5).

4 Measurement of motion in existing structures

4.1 Motion measurements to determine the magnitude and direction of the greatest horizontal acceleration should be made

1) At present at the stage of draft.

on a structural surface supporting the human body at the point of entry to the human subject. Under some conditions, measurements may have to be made on some surface other than at the point of entry of the vibration to the human subjects. In such cases, transfer functions need to be determined.

4.2 If it is found that vibration occurs simultaneously at separate discrete frequencies within the range 0,063 to 1 Hz, then the r.m.s. accelerations at these discrete frequencies should be found by analysing a continuous record of the structural motion during the peak of the storm. The highest magnitude of horizontal acceleration (r.m.s.) at each discrete frequency found for 10 consecutive minutes of the storm peak can then be used to assess the probable response of occupants to the horizontal structural motion at each discrete frequency considered. Vibration outside the range 0,063 to 1 Hz should be filtered at not less than 24 dB per octave.

4.3 When vibration occurs at a single discrete frequency, then the acceleration record at that frequency should be analysed as in 4.2.

4.4 When horizontal motion of a structure occurs simultaneously in more than one direction, then the components of acceleration, in orthogonal directions, may be analysed as in 4.2 and the components added vectorially, taking account of phase.

4.5 When random horizontal motion of a structure occurs in a narrow band concentrated in a one-third octave band or less, the r.m.s value of acceleration within the band should be evaluated with reference to the centre frequency of that band in the same manner as in 4.2.

NOTES

1 Evaluating the acceleration record of a structure as above, the extreme magnitudes of motion referred to in note 5 in 3.6 are taken into account.

2 For tall buildings, the highest magnitudes of acceleration generally occur near the top of the buildings at the first natural frequency of the structure, but the possibility should not be overlooked that unacceptable accelerations may occur elsewhere in such buildings in vibration modes with higher frequencies.

3 In some cases, infrasound generated by the flow of air in ducts can induce the sensation of structural motion in the occupants of the structure. Care should be taken when assessing adverse comments of occupants that a combination of motion and infrasound effects, acting simultaneously, have not combined to exaggerate the sensation of motion (see also A.1.3).

4 Data measurement can be made by recording the output from calibrated systems of accelerometers and matched amplifiers using frequency-modulated tape recorders. Subsequent reduction of the recorded data can be carried out using filters as described in 4.2 and Fast Fourier Transform analysis equipment. To analyse even the minimum time record of 10 min, continuous averaging of record segments will probably be necessary and for 95 % confidence of being within 10 % accuracy at 0,08 Hz, for example, the averaging time for one-third octave frequency analysis should be more than 200 s. Therefore, record segments in excess of 200 s should be used in the analysis.

Annex

Assessment of structural vibration with respect to human response

A.1 Assessment of infrequently induced vibration in buildings used for general purposes for events with duration in excess of 10 min

A.1.1 Satisfactory magnitudes of low-frequency horizontal motion during the worst 10 consecutive minutes of a wind storm with a return period of at least 5 years, for buildings used for general purposes, are given by curve 1 in figure 1 for the probable adverse comment levels of clause 3. These values are for vibration in the horizontal plane of buildings or structures and therefore for any whole-body axis depending upon whether the human is standing, sitting or reclining.

A.1.2 The satisfactory magnitudes of r.m.s. acceleration are for discrete frequencies. If random narrow-band vibrations, vibrations at several discrete frequencies or multi-axis vibrations occur, then assessment should be made in accordance with 4.2, 4.3, 4.4 or 4.5, whichever is appropriate.

A.1..3 If a building is subject to even extremely small oscillations of rotation about a vertical axis, visual effects would exaggerate the sensation of motion and the satisfactory magnitudes of acceleration would be less than those of curve 1 in figure 1.

A.2 Assessment of infrequently induced vibration of off-shore fixed structures for events with duration in excess of 10 min

A.2.1 Satisfactory magnitudes of low-frequency horizontal motion for off-shore fixed structures are given by curve 2 in figure 1 for cases where work of a somewhat critical nature has to be performed. This would be the case where a non-routine task has to be executed or a skilled operation has to be carried out. Above these magnitudes of motion, it is difficult to perform such tasks.

A.2.2 As may be seen, the acceleration amplitudes given by curve 2 in figure 1 for the activities described in A.2.1 above are six times greater than those given by curve 1 in figure 1.

NOTE — For routine tasks such as drilling, an experienced team may often work even in the roughest conditions, the magnitude of acceleration found acceptable being governed by whether the machinery will operate and the motivation of the workers.

A.3 Assessment of frequently induced vibration in buildings used for special purposes for events with duration in excess of 10 min

A.3.1 The available data indicate that the lower threshold of perception of horizontal motion by humans is represented by curve 1 in figure 2. These magnitudes are appropriate for areas where an environment is required to be apparently stationary.

A.3.2 The average threshold of perception represents the mean threshold of perception of horizontal motion for a normal adult population. The magnitudes suggested by curve 2 in figure 2 are appropriate for special buildings where routine precision work is carried out. These magnitudes are four times those given for the activities covered by curve 1 in figure 2.

NOTES

1 Frequent occurrences refer to events of an everyday nature.

2 The perception of motion is assumed to be sensed through proprioceptive cues or vestibular organs rather than through visual cues. Even very small rotational oscillations about a vertical axis can significantly exaggerate the actual magnitude of acceleration acting on the subject.

A.4 Events with duration less than 10 min

A.4.1 A definite procedure for assessing events of short duration can be compiled at a later date as more data become available. It may be appropriate to commence analysis of acceleration records of short duration events when the r.m.s. acceleration rises above that given by curve 2 in figure 2 for the frequency under consideration and to terminate analysis when the r.m.s. acceleration falls below this magnitude.

Table — Acceleration/frequency values at the one-third octave points for the curves in figures 1 and 2

Frequency (centre frequency of one-third octave band) Hz	Acceleration r.m.s., m/s^2			
	Curve 1 Figure 1	Curve 2 Figure 1	Curve 1 Figure 2	Curve 2 Figure 2
0,063	0,081 5	0,489 0	0,012 6	0,050 4
0,080	0,073 5	0,441 0	0,011 4	0,045 0
0,100	0,067 0	0,400 0	0,010 3	0,040 9
0,125	0,061 0	0,366 0	0,009 2	0,037 0
0,160	0,055 0	0,330 0	0,008 3	0,033 0
0,200	0,050 0	0,300 0	0,007 5	0,030 0
0,250	0,046 0	0,276 0	0,006 9	0,027 0
0,315	0,041 8	0,250 0	0,006 1	0,024 0
0,400	0,037 9	0,228 0	0,005 5	0,021 9
0,500	0,034 5	0,207 0	0,004 9	0,019 8
0,630	0,031 5	0,189 0	0,004 45	0,017 8
0,800	0,028 5	0,167 0	0,003 98	0,015 9
1,000	0,026 0	0,156 0	0,003 60	0,014 4

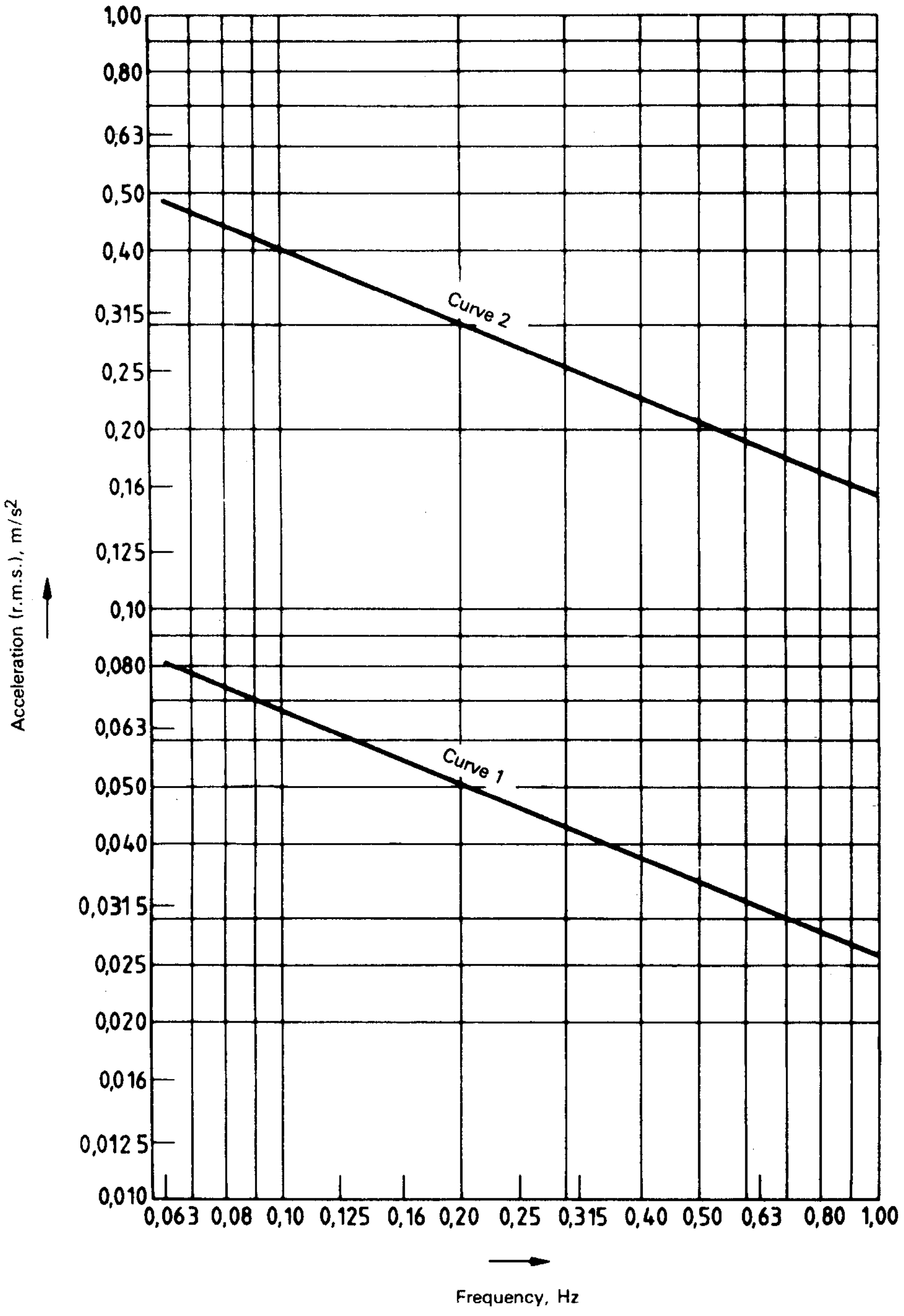

Figure 1 — Suggested satisfactory magnitudes of horizontal motion of buildings used for general purposes (curve 1) and of off-shore fixed structures (curve 2)

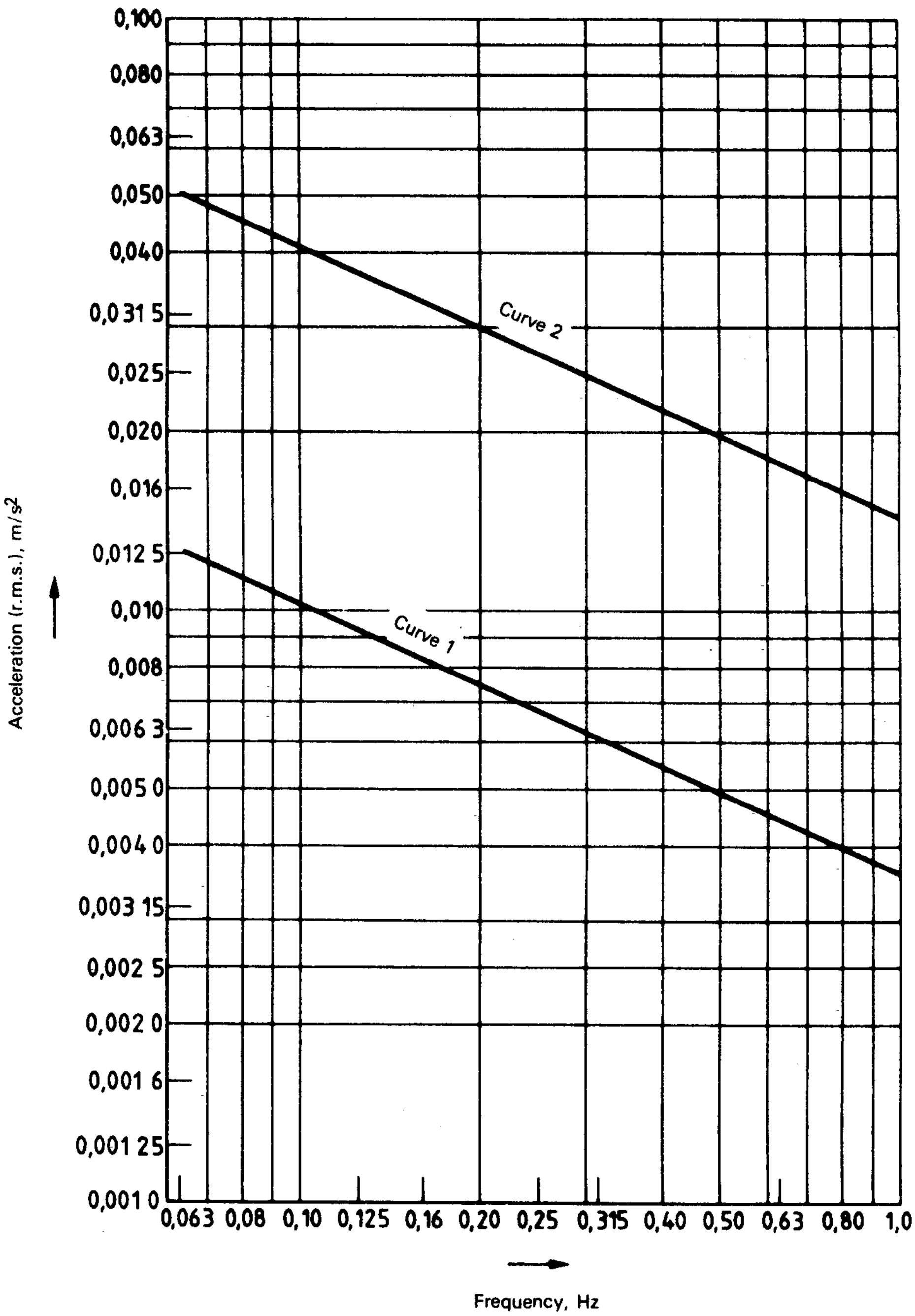

Figure 2 — Average (curve 2) and lower threshold (curve 1) of perception of horizontal motion by humans

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