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Measurement of ride quality

Part 1: Lifts (elevators)

National foreword

This British Standard is the UK implementation of ISO 18738-1:2012.

The UK participation in its preparation was entrusted to Technical Committee MHE/4, Lifts, hoists and escalators.

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

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Measurement of ride quality —

Part 1: **Lifts (elevators)**

Mesure de la qualité de déplacement —

Partie 1: Ascenseurs

Reference number
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Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18738-1 was prepared by Technical Committee ISO/TC 178, *Lifts, escalators, passenger conveyors*.

ISO 18738 consists of the following parts, under the general title *Measurement of ride quality*:

— *Part 1: Lifts (elevators)*

— *Part 2: Escalators and moving walks*

Introduction

The objective of this part of ISO 18738 is to encourage industry-wide uniformity in the definition, measurement, processing and expression of vibration and noise signals that comprise lift ride quality.

The aim of such uniformity is to benefit lift industry clients by reducing variability in the results of lift ride quality measurements caused by differences in the methods of acquiring and quantifying the signals.

This part of ISO 18738 is intended to be referred to by those parties interested in

a) developing manufacturing specifications and calibration methods for instrumentation,

b) defining the scope of the specifications for lift ride quality in contracts, and

c) measuring lift ride quality in accordance with an International Standard.

It is intended to produce lift ride quality measurements which

a) are simple to understand without specialized knowledge of noise and vibration analysis,

b) correlate well with human response to ensure plausibility, and

c) are accountable via calibration procedures which are traceable to national standards.

This part of ISO 18738 refers to ISO 8041 and IEC 61672 and has drawn significantly on the considerable body of research implicit in these standards. However, several special challenges drawing on additional research and development were also recognized.

Experience in the lift industry indicates that evaluation of vibration in terms of peak-to-peak levels is of particular relevance to passenger comfort. It was considered necessary for this part of ISO 18738 to provide a dual form of expression, quantifying both the maximum peak-to-peak and A95 peak-to-peak vibration levels.

To minimize the adverse effects of external influences unique to the lift industry, it was considered necessary to prescribe the prerequisites and method of the measurement process as well as the relevant boundaries (start and end points) over which each signal is quantified.

It was also considered necessary to analyse vertical vibration and vertical motion control separately in order to correlate with human response.

Finally, through the inclusion of algorithms amenable to digital programming, this part of ISO 18738 reflects the commercial need in the lift industry for instrumentation capable of rapid automatic computation of the required signal quantities. Analog systems may be used provided that the requirements of this part of ISO 18738 are met.

Measurement of ride quality —

Part 1:
Lifts (elevators)

1 Scope

This part of ISO 18738 specifies requirements and methodology for the measurement and reporting of lift ride quality during lift motion. It does not specify acceptable or unacceptable ride quality.

NOTE Lift performance parameters are often referenced in conjunction with lift ride quality. Parameters relevant to lift performance include jerk and acceleration. This part of ISO 18738 defines and uses performance parameters where they are integral to the evaluation of ride quality.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041:2009, *Vibration and shock — Vocabulary*

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

ISO 8041:2005, *Human response to vibration — Measuring instrumentation*

IEC 61672-1:2002, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-2:2003, Electroacoustics — Sound level meters — Part 2: Pattern Evaluation Tests

ISO 80000-8:2007, *Quantities and units — Part 8: Acoustics*

ISO/IEC Guide 98:1993, Guide to the expression of uncertainty in measurement (GUM)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 5805, IEC 61672, and ISO 80000-8 and the following apply.

3.1
acceleration
rate of change of *z*-axis velocity, attributed to lift motion control

NOTE It is expressed in metres per second squared (m/s^2).

3.2
vibration
variation with time of the magnitude of acceleration, when the magnitude is alternately greater and smaller than the average acceleration of the lift when no lift motion is present

NOTE 1 It is expressed in metres per second squared (m/s^2).

NOTE 2 The deprecated unit Gal (Galileo) is sometimes used: 1 Gal = 0,01 m/s^2.

3.3
A95
value of acceleration or vibration, within defined boundaries or limits, which 95 % of found values are equal to or less than

NOTE 1 This value is used statistically to estimate typical levels.

NOTE 2 See 5.2.3, 5.4.1 and 5.4.3.

3.4
velocity
rate of change of *z*-axis displacement, attributed to lift motion control

NOTE Velocity is reported as speed and direction of travel. It is given in metres per second (m/s).

3.5
V95
value of velocity, within defined boundaries or limits, which 95 % of found values are equal to or less than

NOTE 1 This value is used statistically to estimate typical levels.

NOTE 2 See 5.5.3.

3.6
axes of measurement
orthogonal reference axes for the measurements, where for lifts of conventional configuration, *x* is the perpendicular to the plane of the car front door (i.e. back to front); *y* is the perpendicular to *x* and *z* (i.e. side to side); *z* is the perpendicular to the car floor (i.e. vertical)

NOTE For lifts of unconventional configuration, the axes should be defined for directions of basicentric coordinate systems for mechanical vibrations influencing human subjects, for a standing person facing the front car door, in accordance with ISO 2631-1.

3.7
lift ride quality
sound levels in the car, and vibration of the car floor, relevant to passenger perception, associated with lift motion

3.8
jerk
rate of change of *z*-axis acceleration, attributed to lift motion control

NOTE 1 The passenger perception of vertical ride quality during jerk is represented by the assessment of vertical vibration during non-constant acceleration. See 5.3 and 5.4.3.

NOTE 2 Jerk is expressed in metres per second cubed (m/s^3).

3.9
peak-to-peak vibration levels
sum of the magnitudes of two peaks of opposite sign separated by a single zero crossing

3.10
sound pressure level
$L_{p,A}$
sound pressure level using frequency weighting A as defined in IEC 61672-1:$L_{p,A} = 10 \lg (p_A^2/p_0^2)$ dB(A)

NOTE 1 The reference sound pressure level, p_0, is 20 µPa (2×10^{-5} Pa).

NOTE 2 The measured sound pressure, p_A, in Pascals (Pa), using frequency weighting A.

3.11
equivalent sound pressure level
L_{Aeq}
average sound pressure level, using frequency weighting A and time weighting "fast", determined within defined boundaries

4 Measuring instrumentation

4.1 General

The measuring instrumentation shall consist of the following:

a) transducers to measure acceleration in each of the three orthogonal axes;

b) a transducer to measure the sound pressure level;

c) data acquisition system;

d) data storage system;

e) data processing system.

4.2 Characteristics

The characteristics of the measuring instrumentation shall be as described in Table 1.

Table 1 — Characteristics of measuring instrumentation

Characteristic	Vibration	Acceleration	Sound
Frequency weighting	Whole body *x*, *y*, *z* (see ISO 8041)	N/A	A-weighted (see IEC 61672-1)
Band limiting	See ISO 8041	10 Hz low-pass filter, (2-pole Butterworth)	N/A
Accuracy[a]	Type 1 (see ISO 8041)	Type 1 (see ISO 8041)[b]	Class 2 (see IEC 61672-1)
Time weighting	N/A	N/A	Fast (see IEC 61672-1)
Environmental	See ISO 8041	See ISO 8041	See IEC 61672-1
Resolution	0,005 m/s^2	0,01 m/s^2	1 dB
Measurement range	20 % above max. instantaneous acceleration to 20 % below min. instantaneous acceleration[c]	20 % above max. acceleration to 20 % below min. acceleration[d]	2 dB below min. to 5 dB above max.[e]

N/A = not applicable

a The signals shall be filtered to exclude aliasing.

b Accuracy in the range from 0 Hz to 1 Hz shall be equal to the accuracy specified for 1 Hz in ISO 8041.

c A range of –1,5 m/s^2 to +1,5 m/s^2 should meet the above requirement.

d A range of 7 m/s^2 to 13 m/s^2 should meet the above requirement.

e A range from 30 dB to 90 dB (A-weighted) should meet the above requirement.

4.3 Processing of vibration data

Vibration data shall be weighted in accordance with ISO 8041 to simulate the human body's response to vibration.

The vibration signals shall be frequency weighted with the whole body *x*, *y* and *z* weighting factors and band limiting as defined in ISO 8041.

For digital sampling systems, uncompressed data shall be used.

4.4 Environmental effects

The instrumentation shall comply with the criteria for mechanical vibration, temperature range and humidity range specified in ISO 8041.

4.5 Sound measurement requirements

The sound measuring system shall comply with the requirements for Class 2 sound level meters as specified in IEC 61672-1:2002.

4.6 Calibration requirements

4.6.1 General

All instrumentation calibrations shall be traceable to national standards. The measurement system shall be calibrated before first use, and following any major repairs or modifications likely to affect the calibration.

4.6.2 Vibration measuring system

Calibration shall include determination of the reading error for sinusoidal input at 8 Hz and at five or more other frequencies approximately equally spaced between 0,1 Hz and 80 Hz, with acceleration amplitudes not less than 0,1 m/s^2.

Calibration shall be in accordance with ISO 8041.

4.6.3 Acceleration measuring system

Calibration shall be at 8 Hz and at 0 Hz, as follows.

a) At 8 Hz, the reading error shall be determined for at least five equally spaced acceleration amplitudes between 0,01 m/s^2 and 2,0 m/s^2. Calibration shall be in accordance with ISO 8041.

b) At 0 Hz, an accuracy check shall be performed. The system accuracy from 0 Hz to 1 Hz shall be equivalent to the accuracy specified in ISO 8041 for 1 Hz.

4.6.4 Sound measuring system

Calibration of the sound measuring system shall be carried out with Class 2 sound level meters as specified in IEC 61672-2:2003.

5 Evaluation of ride quality

5.1 Boundaries of calculation

The following boundaries shall be used to define the regions over which signal quantities are calculated (see Figure 1).

Boundary 0 at least 0,5 s before commencement of door closing at the departure terminal floor.

Boundary 1 500 mm after commencement of lift motion from the departure terminal floor.

Boundary 2 500 mm before cessation of lift motion at the arrival terminal floor.

Boundary 3 at least 0,5 s after completion of door opening, or cessation of lift motion, at the arrival terminal floor, whichever occurs last.

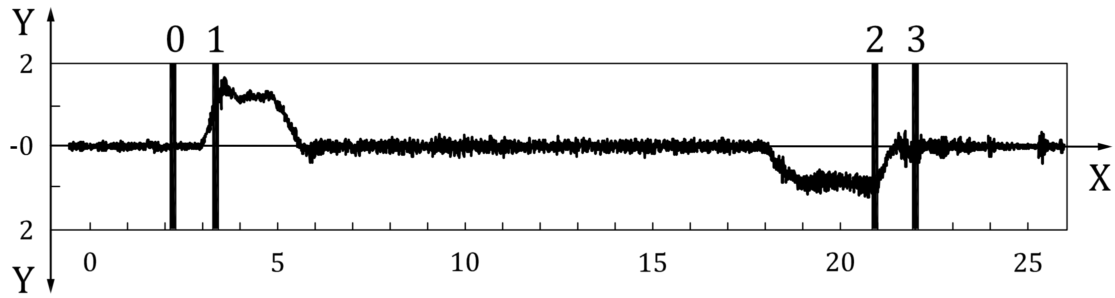
NOTE 1 Boundaries 1 and 2 have been empirically derived to allow the signals resulting from lift motion to be evaluated separately from the signals resulting from door operation. In rare cases however, boundaries 1 or 2 can include a dominant door operation effect, or can exclude a dominant region of a signal resulting from lift motion. In such cases, subject to agreement by the parties involved, it is permitted to adjust either boundary sufficiently to prevent this, when quantifying a signal resulting from lift motion.

Boundary 1 or 2 should be

a) increased to more than 500 mm if the vibration or sound of door operation dominates a signal resulting from lift motion 500 mm from a terminal (e.g. if the vibration or sound of door close operation decays abnormally slowly), and

b) decreased to less than 500 mm if there is dominant vibration or sound in the signal resulting from lift motion which would otherwise be excluded from the calculations (e.g. vibration of a problematic hydraulic lift during leveling into the floor).

NOTE 2 Boundaries 0 and 3 have been defined to include the commencement and cessation of lift motion. This ensures accuracy of the velocity calculation described in 5.5.1. Boundaries 1 and 2 have been defined based on a distance to exclude door operation and simplify signal processing.



Key

0 boundary 0

1 boundary 1

2 boundary 2

3 boundary 3

Y acceleration, m/s^2

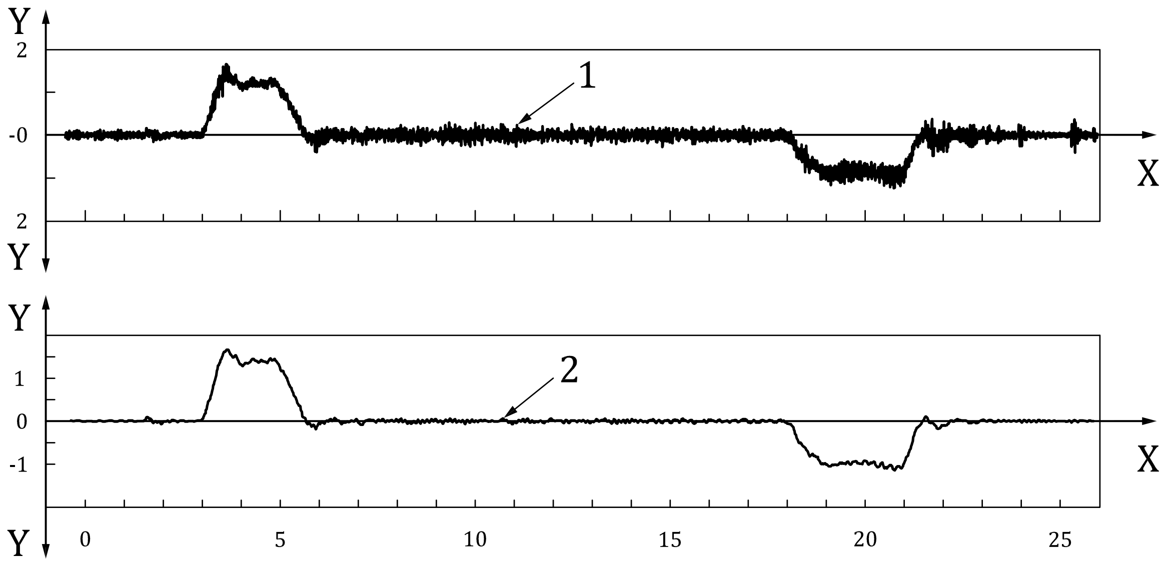
X time, s

Figure 1 — Boundaries of calculation shown on a typical *z*-axis acceleration signal

5.2 Acceleration and deceleration

5.2.1 General

The values of acceleration and deceleration shall be calculated by applying a 10 Hz low-pass filter to the unweighted *z*-axis signal, as shown in Figure 2. The 10 Hz low-pass filter shall be a 2-pole Butterworth filter as described in Table 1.



Key

1 unweighted *z*-axis signal

2 10 Hz filtered *z*-axis signal

Y acceleration, m/s²

X time, s

Figure 2 — Unweighted and 10 Hz filtered *z*-axis signal

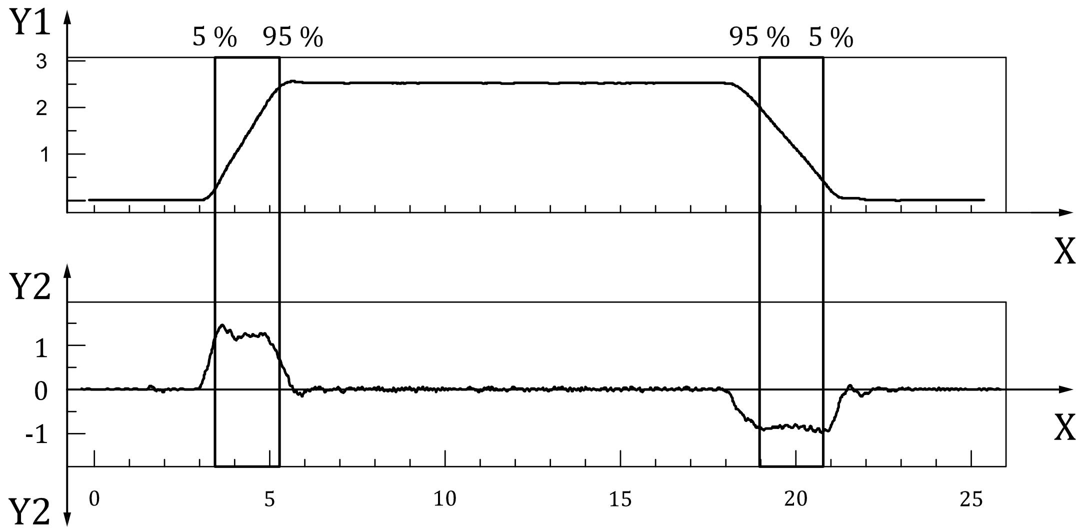
5.2.2 Maximum acceleration and deceleration

The maximum acceleration shall be the largest absolute value found in the signal where the speed is increasing. The maximum deceleration shall be the largest absolute value found in the signal where the speed is decreasing.

NOTE The acceleration and deceleration are quantified in order to confirm motion control settings to which the ride quality results apply.

5.2.3 A95 acceleration and deceleration

The A95 acceleration shall be calculated from 5 % to 95 % of maximum velocity during the first half of the signal between boundaries 0 and 3. The A95 deceleration shall be calculated from 95 % to 5 % of maximum velocity during the second half of the signal between boundaries 0 and 3 (see Figure 3).



Key

Y1 velocity, m/s

Y2 acceleration, m/s^2

X time, s

Figure 3 — Calculation of A95 acceleration and deceleration

5.3 Jerk

5.3.1 General

The influence of jerk on ride quality shall be assessed using vertical vibration as defined in 5.4.3.

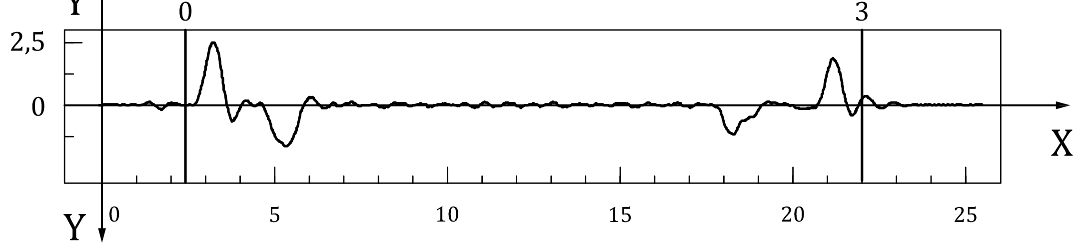
NOTE 1 Jerk is quantified in order to confirm motion control settings to which the ride quality results apply.

Jerk (shown in Figure 4) shall be calculated from the 10-Hz filtered *z*-axis acceleration signal as defined in 5.2 using the mid-point of a 0,5 s duration running least squares best-fit line to calculate the slope as a function of time of the acceleration signal.

NOTE 2 The duration of the best-fit line has been empirically determined.

5.3.2 Maximum jerk

The maximum jerk shall be the greatest absolute value of the jerk signal between boundaries 0 and 3, as shown in Figure 4.



Key

Y jerk, m/s^3

X time, s

Figure 4 — Jerk signal

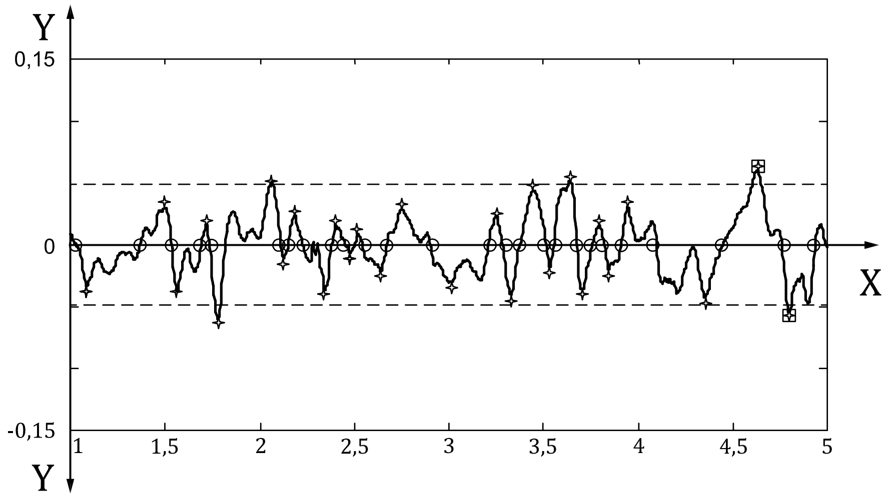
5.4 Vibration

5.4.1 General

Vibration shall be determined from the weighted acceleration signals in the time domain in accordance with 4.3.

The vibration signal shall be evaluated for peak-to-peak levels (see 3.9). The maximum peak-to-peak vibration level is the largest of all the peak-to-peak values found between defined boundaries. The A95 (typical) peak-to-peak vibration level is that value which 95 % of the peak-to-peak levels, between defined boundaries, are equal to or less than.

Peak-to-peak vibration, maximum peak-to-peak vibration and A95 (typical) peak-to-peak vibration are illustrated in Figure 5 and described in detail in Annex A.



Key

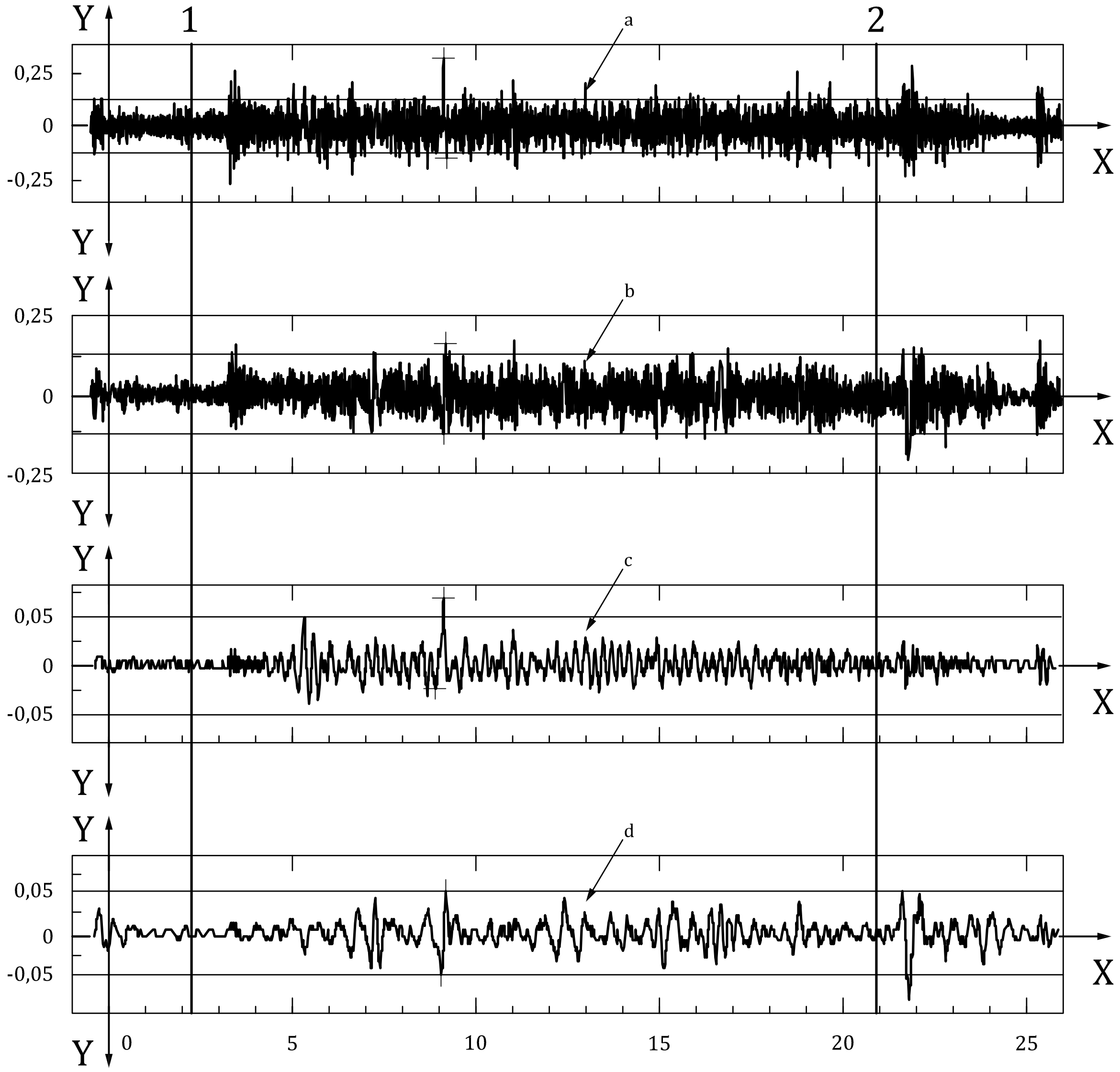
Y	vibration, m/s^2
X	time, s
———	vibration
○	zero-crossing
✧	peak values
□	maximum peak-to-peak values
– – – –	A95 peak-to-peak values

Figure 5 — Illustration of peak-to-peak calculations

5.4.2 Horizontal vibration: *x*- and *y*-axes

The peak-to-peak vibration levels of the weighted *x*- and *y*-axis time domain signals between boundaries 1 and 2 shall be calculated in accordance with 5.4.1 (see also Figure 6).

Both the maximum peak-to-peak and the A95 peak-to-peak vibration levels shall be reported.



Key

Y vibration, m/s²

X time, s

a *x*-axis (unweighted).

b *y*-axis (unweighted).

c *x*-axis (weighted).

d *y*-axis (weighted).

Figure 6 — Unweighted and weighted horizontal vibration signals

5.4.3 Vertical vibration: *z*-axis

The peak-to-peak vibration levels of the weighted *z*-axis time domain signal between boundaries 0 and 3 shall be calculated in accordance with 5.4.1. The calculated vibration shall be reported for the following two distinct regions of the vibration signal as defined in Annex B (see Figure 7):

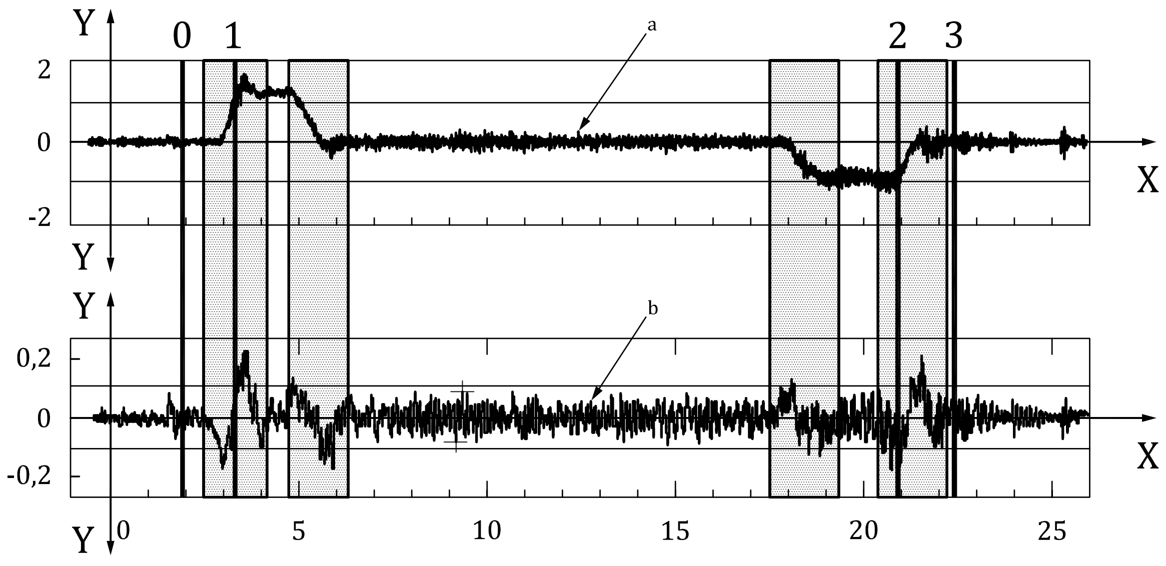
a) constant acceleration region where the acceleration attributed to motion control is constant;

b) non-constant acceleration region.

Both the maximum peak-to-peak and the A95 peak-to-peak vibration levels shall be reported for the constant acceleration region.

The maximum peak-to-peak vibration level shall be reported for the non-constant acceleration region.

NOTE Because of the requirement to minimize performance times, higher vibration levels may occur during non-constant acceleration regions of the signal. The procedure outlined in Annex B is used to define the regions and allow vertical vibration to be calculated separately for each region.



Key

Y vibration, m/s²

X time, s

a *z*-axis (weighted).

b *z*-axis (unweighted).

▨ non-constant acceleration region, within boundaries 0 and 3

☐ constant acceleration region, within boundaries 1 and 2

Figure 7 — Weighted and unweighted *z*-axis vibration signals showing constant and non-constant acceleration regions

5.5 Velocity

5.5.1 General

The value of velocity attributed to motion control shall be measured directly or calculated by integration of the 10 Hz low pass filtered signal defined in 5.2 (see Figure 8).

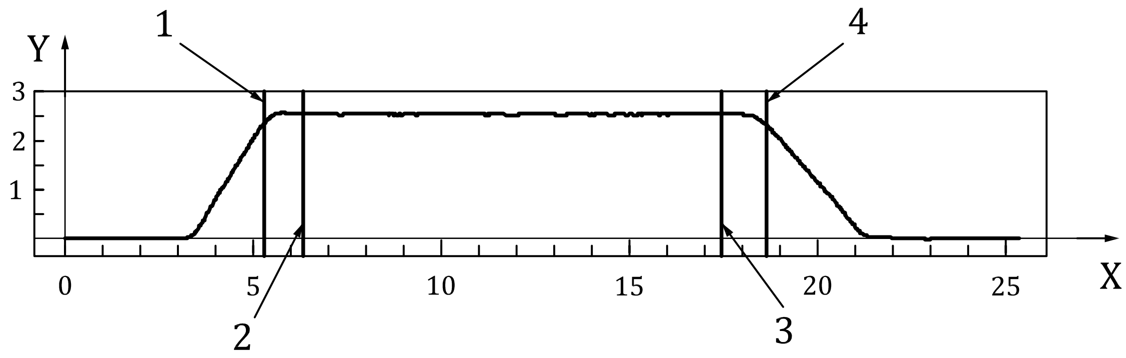
NOTE The velocity is quantified in order to confirm motion control settings to which the ride quality results apply.

5.5.2 Maximum velocity

The maximum velocity shall be the highest absolute value of the velocity.

5.5.3 V95 velocity

The V95 velocity shall be calculated between the boundaries from 95 % of maximum velocity during acceleration plus 1 s until 1 s before 95 % of maximum velocity during deceleration, as shown in Figure 8.



Key

Y velocity, m/s

X time, s

1 95 % of maximum velocity during acceleration

2 1 s after 95 % of maximum velocity during acceleration

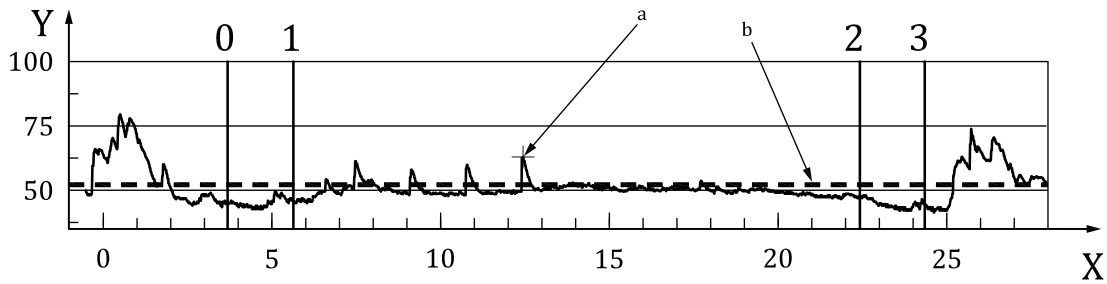
3 1 s before 95 % of maximum velocity during deceleration

4 95 % of maximum velocity during deceleration

Figure 8 — Calculation of V95 velocity

5.6 Sound

The maximum and L_{Aeq} sound pressure levels between boundaries 1 and 2 shall be calculated and expressed as defined in 3.10, 4.5, 5.1 and Table 1, and as shown in Figure 9.



Key

Y A-weighted sound pressure level, dB

X time, s

a Maximum sound level.

b L_{Aeq} sound pressure level.

Figure 9 — Maximum and L_{Aeq} sound pressure levels

6 Procedure and expression of results

6.1 Preparation for measurement and expression of results

6.1.1 General

The measurements should be taken at a time of day agreed by the parties involved, in order to prevent disputes over the possible effects of ambient noise.

Sound measurements should not be carried out if

a) any sound sources are present which are extraneous to the normal operation of the lifts or the building plant and equipment, and

b) any party involved deems any such source to be likely to affect the measurement results.

NOTE For example, building environmental noise, audible construction, refurbishment or cleaning work is likely to affect the measurement results.

If extraneous sound sources are present in the building, care shall be taken to ensure the measurement occurs over an interval where they are absent. If this is not feasible, the presence of these sources shall be noted in the reporting of the results. Under normal building conditions, unless agreed otherwise by the parties involved for technical or logistical reasons, auxiliary equipment and building plant and equipment should operate as described in 6.1.2 to 6.1.4 during the measurement process.

6.1.2 Auxiliary car equipment

Car fan, air conditioning, audible alarms, chimes and announcement features should be off. If for practical reasons any of this equipment cannot be turned off, this shall be stated in the reporting of results.

NOTE Only the vibration and sound associated with lift motion are being assessed.

6.1.3 Auxiliary landing equipment

Alarms, chimes and announcement features, which are audible in the car, should be turned off.

6.1.4 Building plant and equipment

All building plant and equipment, including the adjacent lift(s), should remain in normal service.

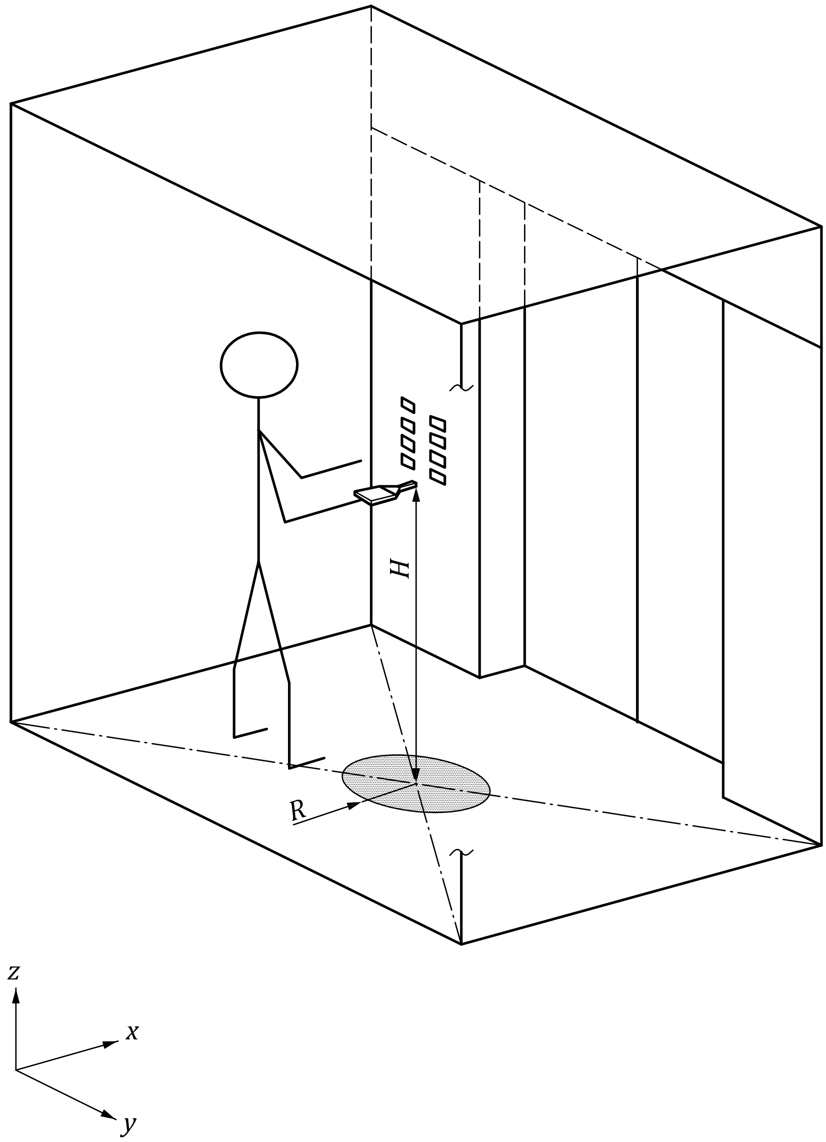
6.2 Location of transducers

6.2.1 General

Transducers for the measurement of vibration shall be placed on the car floor within a 100 mm radius of the centre of the floor (see Figure 10). The transducer for the measurement of sound shall be located 1,5 m ± 0,1 m above the same region of the floor, aligned along the *x*-axis, and aimed directly at the front car door.

NOTE Human judgement involving careful positioning of the vibration measuring transducers and level hand holding of the sound transducer is normally sufficient to meet the above requirements (see 6.3).

Dimensions in metres



Key

R = 0,15

H = 1,5 ± 0,1

Figure 10 — Location of transducers

6.2.2 Coupling of instrumentation to floor

The instrumentation shall be placed on any car floor coverings which are normally present. If floor coverings are not normally present, then none shall be introduced. The feet of the instrumentation shall exert a pressure on the floor of not less than 60 kPa, which is approximately human foot pressure (see Note). The instrumentation shall remain in stable contact with the floor throughout the measurement process.

NOTE The instrumentation placed on the car floor is intended to measure vibration which is representative of the conditions experienced by a person standing on the floor. The instrumentation design should minimize, in all three axes, any mechanical decoupling from the floor which could allow attenuation or amplification associated with mechanical resonance to invalidate any measurements from the human perception viewpoint. The minimum requirement for adequate coupling is thus considered to be the application of at least human foot pressure.

EXAMPLE Assuming for a standing passenger, a weight distribution of 90 % on the heels, and the heel contact area circumference equal to 0,25 m:

$C = \pi \times d$

$A = \pi \times r^2$

where

C	is the circumference;
d	is the diameter = 0,079 6 m;
r	is the radius = 0,039 8 m;
A	is the surface area of contact = $\pi \times (0{,}039\ 8\ \text{m})^2 = 0{,}004\ 97\ \text{m}^2$ (for one foot).

Using the assumption that 90 % of the weight is on the heels and 10 % is on the front of the foot, and that the average person has a mass (m) of 68 kg, it can be calculated that the maximum mass acting on any area of contact is $\frac{0{,}9 \times 68}{2}$kg for one foot, or 30,6 kg.

Using 30,6 kg and a surface area of 0,004 97 m^2, the average pressure p is

$$\frac{mg}{A} = \frac{30{,}6 \times 9{,}81}{0{,}00497} = 60\ 400\ \text{Pa} > 60\ \text{kPa}$$

where g is the acceleration due to gravity (= 9,806 65 m/s^2).

6.3 Personnel

No more than two persons shall be present in the lift. When two persons are present during the measurement, they should stand in locations that do not significantly unbalance the lift. Each person shall remain still and quiet during the measurement process. No person(s) shall place their feet within 150 mm of the vibration measuring transducers, in order to prevent any localized deflections of the platform and floor coverings influencing the measurements. No person(s) shall stand within 300 mm of the sound measuring transducer, in order to prevent alteration of measured sound levels. No person(s) shall stand between the sound measuring transducer and the car doors.

6.4 Measurement process

For the purpose of data acquisition, the measurements shall include the door close operation at the departure terminal floor, the full travel of the lift from terminal to terminal, the entire door open operation and cessation of lift motion at the arrival terminal floor, with the addition of 0,5 s at each end of the run (see 5.1). At least one UP run and one DOWN run shall be measured. Any run deemed to be non-typical due to unusual or unforeseen events should be repeated. Non-typical data may be discarded.

NOTE Repeated measurements are encouraged to increase statistical confidence.

6.5 Reporting of results

The results shall be reported, subject to the postponement of the measurement of sound as described in 6.1.1. General information, ride quality results and performance characteristics (for reference) shall be reported as follows.

a) General information

— the date and time of the measurement;

— the instrument identification number and the date of last calibration;

— the name(s) of the persons present during measurement and the name of the organization carrying out the measurement;

— the status of any equipment as defined in 6.1.2, 6.1.3 and 6.1.4;

— the building identification;

— the lift identification number;

— the direction of travel and the departure and arrival terminal floor designations.

b) Ride quality results

— the maximum and L_{Aeq} sound pressure levels during lift travel;

— the maximum peak-to-peak and the A95 (typical) peak-to-peak *x*- and *y*-axes vibration levels during lift travel;

— the maximum peak-to-peak *z*-axis vibration levels during the non-constant acceleration region of lift travel;

— the maximum peak-to-peak and the A95 (typical) peak-to-peak *z*-axis vibration levels during the constant acceleration region of lift travel.

c) Performance characteristics (for reference)

— the maximum and V95 (typical) velocity;

— the maximum and A95 (typical) acceleration and deceleration;

— the maximum jerk.

In reporting numerical values, the number of significant figures quoted shall not exceed that which is justified by the estimated uncertainty. In the case of a dispute over reported numerical values, the matter shall be resolved by referring to GUM (Guide to the expression of uncertainty in measurement). Any estimates of uncertainty should be calculated at the 95 % confidence level.

Annex A
(normative)

Calculation of peak-to-peak vibration levels

The procedure for calculating peak-to-peak vibration levels, maximum peak-to-peak vibration levels, and A95 (typical) peak-to-peak vibration levels is as follows.

Step 1: Locate the first, second and third zero crossing points of the weighted signal, after the first boundary of calculation.

Step 2: Find the largest positive signal value and the largest negative signal value between zero crossing points 1 and 3.

Step 3: Sum the absolute values of these two quantities and store the corresponding sum as, for example, P_{123} where P is the peak-to-peak value.

Step 4: Repeat steps 2 and 3 between zero crossing points 2 and 4, 3 and 5, 4 and 6, etc. Store all the peak-to-peak values up to the last zero crossing point before the last boundary of calculation as, for example, P_{123}, P_{234}, P_{345}, P_{456}, etc.

Step 5: Calculate the maximum peak-to-peak level using the following process:

$P_{\text{max}} = (P_{123}, P_{234}, P_{345}, \ldots)_{\text{max}}$

(i.e. the highest of the stored peak-to-peak values).

Step 6: Calculate the A95 peak-to-peak level using the following process:

$P_{\text{A95}} = (P_{123}, P_{234}, P_{345}, \ldots)_{\text{A95}}$

Annex B
(normative)

Calculation of constant and non-constant acceleration regions

The procedure for defining constant and non-constant acceleration regions is as follows.

Step 1: Filter the acceleration signal defined in 5.2.1 using a 1 Hz low-pass 2-pole Butterworth filter.

Step 2: Calculate the slope as a function of time of the mid-point of a 1 s duration running least-squares best-fit line of the filtered acceleration signal calculated in step 1.

Step 3: Identify all sections on the time axis for which the absolute value of the slope calculated in step 2 exceeds 0,3 m/s^3.

Step 4: To each section identified in step 3, add 0,5 s before and after.

Step 5: Define the non-constant acceleration region to be the sections produced in step 4.

Step 6: Define the constant acceleration region of the signal to be the time axis between boundaries 1 and 2 excluding the sections produced in step 4.

NOTE The procedure outlined above has been empirically determined. The 1 s duration least-squares estimate in step 2 is used to define the two regions of acceleration, and is not used to calculate jerk values.

Bibliography

[1] ISO 2631-1:1997/Amd 1: 2010, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

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