# International Standard ISO 8002

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

# Mechanical vibrations — Land vehicles — Method for reporting measured data

*Vibrations mécaniques — Véhicules terrestres — Méthode de présentation des résultats des mesures*

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**Descriptors :** vibration, land vehicles, self-propelled machines, vibration tests, data representation.



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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.



International Standard ISO 8002 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

# Mechanical vibrations — Land vehicles — Method for reporting measured data

## 0 Introduction

It is often useful to compare and/or to compile measured vibration data from various sources. These endeavours are more difficult when the data are presented in different forms, such as constant bandwidth r.m.s. curves (of various bandwidths), proportional bandwidth curves, or power spectral density (PSD) curves, sometimes on linear scales and sometimes on logarithmic scales. Tedious and time-consuming mathematical transformation and replotting are therefore necessary, and this introduces the risk of errors.

This International Standard specifies a uniform method for reporting data to facilitate comparing and compiling data.



The results of a measurement of random vibration are an estimate based on a sample. This International Standard specifies the analysis parameters to be reported so that the statistical precision of the reported data can be determined.

The measured vibration on land vehicles is a function both of the vehicle and of external factors, such as the operating conditions and the road or terrain profile. For work machines, the operating conditions are the machine work cycle and may vary considerably between segments of a specific work cycle. This International Standard specifies the reporting of the operating conditions, of the road or terrain conditions and of the work cycle (for work machines) as related to the reported vibration data. This information is necessary to assess and to compare data.

This International Standard emphasizes the need to include most of the relevant information on the curves or tables of results. The intent is to encourage putting details and results in a complete form on a few pages. This will facilitate compiling and comparing data and will facilitate international use of the data because the amount of translation necessary to identify the data will be reduced.

The purpose of this International Standard is to specify complete and uniform reporting of parameters, methods and results. It is not the purpose of this International Standard to specify any particular method to be used in the work itself.

An example which meets the minimum requirements of this International Standard is given in the annex.

## 1 Scope

This International Standard specifies a uniform method for reporting measured vibration data for all forms of land vehicles and work machines.

## 2 Field of application

This International Standard applies to reporting data to be used for certain types of structural testing of land vehicles and work machines or their components and to reporting data on vibration measured at the vehicle-occupant interface.

This International Standard applies to original reports of measured data and to reports or other publications which assess, summarize, compare or compile measured data from original reports.

It is not applicable to the reporting of any form of transfer function or other dynamic property of a system as derived from the measured data.

## 3 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 2631, *Evaluation of human exposure to whole-body vibration.*

ISO 4865, *Vibration and shock — Methods for analysis and presentation of data.*[1)]

ISO 5008, *Agricultural wheeled tractors and field machinery — Measurement of whole-body vibration to the operator.*

ISO 5349, *Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration.*

IEC Publication 225, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

## 4 Definitions

For the purposes of this International Standard, the terminology given in ISO 2041 and ISO 4865, and the following definitions apply.

1) At present at the stage of draft.

**4.1 detrending** : Any time domain process to reduce or remove frequency components the period of which is longer than the record length.

**4.2 land vehicle**: A self-propelled device for carrying passengers, goods, or equipment, for example, car, bus, highway truck or train.

**4.3 magnitude window**: The incremental range of magnitude of the time history, as used to calculate the probability functions (magnitude distributions) of vibration data.

**4.4 work machine**: A self-propelled or mobile device designed to alter or transmit energy and force for the performance of useful work, for example, tractor, loader, grader, ditcher or combine. Also a self-propelled device designed for carrying goods, material, or equipment on a work site, for example, dumper or fork-lift truck.

## 5 Symbols and subscripts

### 5.1 Symbols

$a$ Acceleration (m/s$^2$)

$B$ Bandwidth of a filter (Hz)

$g$ Acceleration due to gravity (m/s$^2$)

$T$ Total time of analysed data (s)

$W$ Magnitude window width used in the calculation of probability density, as a proportion of the r.m.s. of the data.

### 5.2 Subscripts $x$, $y$, $z$

These lower case subscripts refer to the direction of rectilinear vibrations. For vehicle-occupant interface vibration, these shall be stated in accordance with ISO 2631 and ISO 5349. For vehicle or vehicle component vibration, $a_x$ is the fore-and-aft direction of vehicle motion, $a_y$ is the side-to-side direction, and $a_z$ is the vertical direction. If it is necessary to denote the positive direction of vehicle motion, it should be done in accordance with the relevant International Standards.

### 5.3 Subscripts $rx$, $ry$, $rz$

These lower case subscript pairs refer to rotational vibrations about the $x$, $y$ and $z$ axes, i.e. roll, pitch and yaw.

### 5.4 Subscript capital letters

Subscript capital letters refer to the location of the measurements.

## 6 Uniform method of reporting

### 6.1 Reporting of spectral data

Curves or tables of spectral data shall conform to table 1.

For curves or tables of spectral data, the information stated on the curve sheet or table sheet shall include that given in 7.1, 7.2, 7.3, 8.1 c), 8.1 d), 8.1 e), 9.2 a), 9.2 b), 9.2 c), 9.2 e), 9.3 a) and 9.3 b).



### 6.2 Reporting of magnitude distribution data



Magnitude distribution data shall be reported as zero-mean probability density curves of the instantaneous values of the acceleration, normalized to the r.m.s. value. The curves shall be on logarithmic scales for probability density and linear scales for standard deviation (that is, a semi-logarithmic plot with logarithmic ordinates and linear abscissae). The abscissae shall also include a secondary scale in metres per second squared. The analysed data shall be plotted at the centre of the magnitude window. The Gaussian probability density function shall be included on the curve sheet for reference purposes.

NOTES

1 A standard Gaussian probability density function can be shown if the data is analysed with a magnitude window width of 0,5 standard deviations or smaller. For larger magnitude window widths, Gaussian probability density values should be calculated and shown for the magnitude window width used in the data analysis.

**Table 1**

| Type of data | Form | Scale |
|---|---|---|
| Vehicle-occupant interface: | | |
| Whole-body | Third-octave bandwidth r.m.s. acceleration (unweighted) versus frequency (in conformity with ISO 2631) | Logarithmic on both axes |
| Hand | Octave or third-octave bandwidth r.m.s. acceleration (unweighted) versus frequency (in conformity with ISO 5349) | Logarithmic on both axes |
| All other | Acceleration power spectral density (PSD) versus frequency | Linear on both axes<br>See the note |

NOTE — Acceleration power spectral density may be plotted on logarithmic scales on both axes if the data range is so large as to make linear scales impractical.

Logarithmic scales are usually used to present data analysed by proportional bandwidths.

2 In some cases, the data may be adequately presented as the cumulative probability distribution as an alternative to the probability density. If cumulative probability distribution data are presented, it should be for the zero-mean instantaneous values of the acceleration, normalized to the r.m.s. value. Cumulative probability distribution data should be plotted on normal probability graph paper with the Gaussian straight line shown as a reference.

For curves or tables of magnitude distribution data, the information stated on the curve sheet or table sheet shall include that given in 7.1, 7.2, 7.3, 8.4, 9.2 a), 9.2 b), 9.2 c), 9.2 e), 9.3 a) and 9.3 b).

### 6.3 Reporting of measured or compiled data

The reporting of measured or compiled data shall include the information specified in clauses 7, 8 and 9, except as indicated in those clauses. Symbols used to designate the information shall be in accordance with clause 5.

NOTE — The following clauses specify the minimum information to be reported and should not be construed to limit reports to the required minimum.

## 7 Measured data



**7.1** The location of the measurement point on the vehicle and the direction of the sensitive axis of the transducer shall be clearly stated. The location of the measurement point shall be referenced, by dimensions, to the standard coordinate system as specified in the relevant International Standards for the particular type of vehicle or machine concerned. If no such standard exists, the location shall be referenced, by dimensions, to the centre of an identified axle.

**7.2** The total r.m.s. acceleration of the reduced data, calculated from the time domain and extending over the same frequency range as the spectral data, shall be reported.

NOTE — The reason for reporting the total r.m.s. acceleration, calculated from the time domain, is that this provides a cross-check of the spectral data. The total r.m.s. acceleration in the time domain should be equal to that in the frequency domain.

If the values are significantly different, there is an error in the analysis, such as wrong scaling, wrong correction factor for the sampling window function, or program errors. The comparison of the total r.m.s. acceleration in the time domain to that in the frequency domain requires that both be calculated over the same frequency range. Therefore, the value in the time domain should be calculated from the data remaining after trends have been removed. A difference in values between the time domain and frequency domain can occur if the first few frequency channels are disregarded because of the difficulty in regulating the zero of the measurement chain. However, usually this difference will be small because if the values near 0 Hz are large, then detrending should be carried out.

**7.3** The stationarity of the data shall be reported as the smallest nominal level of significance (0,01; 0,025; 0,05) at which the hypothesis that the data are stationary is not rejected. (For example, as calculated from a run test or a trend test of sample mean values and sample mean square values.)

The sample values (observations) for the tests for stationarity shall encompass the same time-history data as does each reported r.m.s. acceleration value and spectrum. The number of observations and the time interval used in each set of observations shall be reported along with at least a general description of the test for stationarity.

NOTE — Practical mathematical tests for stationarity depend on several assumptions and often test only whether the data are at least weakly stationary. However, for many practical uses of the results of power spectral density analysis, the vibration can be considered as stationary if it is at least weakly stationary. However, even in cases where the stationarity hypothesis is not rejected, caution should be exercised in the interpretation of extreme values in the probability density function. Knowledge of the physical system tested and the operating conditions during the test is often a practical guide as to the stationarity of the data. Mathematical tests for stationarity are discussed in BENDAT, J.S. and PIERSOL, A.G., *Random Data: Analysis and Measurement Procedures,* John Wiley and Sons, New York, 1971.

## 8 Parameters of analysis

**8.1** For all forms of spectral analysis, the following information shall be reported:

a) The analysis method used, analogue or digital.

b) Preprocessing filters, reported in terms of cut-off frequency and slope (in decibels per octave); in the case of digital analysis, this includes the anti-aliasing filter and any detrending filter.

c) The resolution bandwidth (as distinguished from the frequency range of the analysis); in the case of proportional bandwidth analysis, it is sufficient to state the value of the proportion (for example, one-twentieth octave, one-third octave, 5 % of centre frequency).

d) The total duration of the data, in seconds, that are analysed and reported.

e) The statistical precision of spectral estimates of the data; in the case of proportional bandwidth analysis, the statistical precision stated shall be for the narrowest bandwidth (that is, the lowest centre frequency) reported. The statistical precision shall be stated in percentage terms, and calculated for a 95 % confidence level (that is, the stated statistical precision shall be 1,96 times the normalized standard error), based on the random error in a sample (measurement) from a population having a normal (Gaussian) distribution.

f) If a swept filter (scanning filter) analyser is used, the sweep rate (analysis rate), in hertz per second or in octaves per minute, and the total analysis time [in addition to the total duration of the data, see 8.1 d)].

g) Any additional data processing or any additional steps used in the analysis to arrive at the reported data, reported in detail using the terminology given in ISO 2041 and ISO 4865.

**8.2** For analogue spectral analysis, the following information shall be reported, in addition to that specified in 8.1:

a) the class of octave or third-octave band filters, in accordance with IEC Publication 225;

b) the slopes (in decibels per octave) of constant bandwidth filters.

**8.3** For digital spectral analysis, the following information shall be reported, in addition to that specified in 8.1:

a) the specific method used (such as continuous process digital, Fast Fourier Transform, mean lagged product, etc.);

NOTE — Continuous process digital refers to real-time analysis with digital bandpass filters. Mean lagged product is sometimes called the Blackman-Tukey method and refers to the consecutive processes of transforming the time data to the autocorrelation (autocovariance) estimate to the power spectrum estimate.

b) the sampling frequency;

c) the analysis range (that is, from the minimum to the maximum frequencies);

d) the sampling window function and the correction factor used for the sampling window function; if the analyser automatically scales the spectrum so as to have the same r.m.s. or mean square acceleration value in the frequency domain as in the time domain, this should be stated in the report;

e) the slopes (in decibels per octave) of digital filters used in continuous process digital analysis.

**8.4** If the magnitude distribution analysis is reported, it shall be reported for the same data used to report spectral data. The following information shall be reported along with the magnitude distribution analysis:

a) the sampling frequency;

b) the magnitude window width as a proportion of the r.m.s. value;

c) the total duration of the data, in seconds, that are analysed and presented;

d) the bandwidth of the data, if it is different from the analysis range of the spectral data.

## 9 Test conditions

**9.1** The following information pertaining to the instrumentation shall be reported:

a) The type of accelerometer (piezoelectric, piezoresistive, strain-gauge, etc.), and manufacturer and model number.

b) The following accelerometer characteristics and mounting:

— the accelerometer amplitude range for linear amplitude response,

— the accelerometer natural frequency and the frequency range over which the amplitude response is within a stated percentage of linear response,

— the accelerometer nominal voltage or charge sensitivity shall be stated in millivolts per metre per second squared or in picocoulombs per metre per second squared,

— the method of mounting the accelerometer.

NOTE — The information on characteristics given in 9.1 b) may be that stated in the manufacturer's instrument specifications.

c) A flow chart of instrumentation showing transducer, telemetry, tape recorder, etc. State whether a dummy channel was used to detect spurious transients. All important instrument performance characteristics shall be reported, including, in particular, the frequency response, measurement range and accuracy of each instrument. Alternatively, the instruments can be identified by their generic name, commercial manufacturer and model number.



d) The calibration method, the calibration span and the system gain of the instrumentation system (the complete chain of instruments) as used for the test. The calibration span shall be reported as the positive and negative extreme values of instantaneous acceleration which the instrumentation system was adjusted to measure during the test, for example, as $\pm$ 20 $m/s^2$. The system gain shall be reported in volts or millivolts (as appropriate) per metre per second squared.

e) The cut-off frequencies of any filters used in conjunction with recording the data, as distinguished from the preprocessing filters [see 8.1 b)], used in analysing the data.

**9.2** The following information pertaining to the land vehicle or work machine shall be reported:

a) A general description of the land vehicle or the work machine (automobile, bus, agricultural tractor, etc.) in sufficient detail to distinguish it from other types of land vehicles or work machines within the industry. The terminology shall comply with the relevant International Standards.

b) Unladen vehicle or machine mass and wheelbase.

c) Total lumped mass of any load carried during the test (this includes occupants of transportation vehicles), tyre pressure, and total lumped mass distribution of the vehicle or machine as tested; the total lumped mass distribution shall be stated as the centre of gravity location dimensioned to the coordinate system specified in 7.1.

d) A description of the components of the vehicle or machine which might both have an effect on the measured vibration data and differ significantly in their dynamic effects from analogous components on other vehicles or machines of the same general description; this might include the chassis suspension, tyre size and type, counterweights or ballast, mounted heavy equipment, etc. For occupant vibration data, in addition to the factors listed above, this also might include the seat suspension, the seat and back-rest design, and the restraint system used by the occupant.

e) Height and mass of the occupant, if measurements at the vehicle-occupant interface are reported. The report shall include at least a brief description of the subject's orientation relative to the principal direction of vehicle motion if the orientation is other than the normal seated orientation typical of the type of vehicle.

**9.3** The following information pertaining to the operating conditions during the test shall be reported:

a) A plan view of the test site, stating distances, slopes, gear ratio used and speeds (and activity for work machines). The segments of the test site shall be identified in relation to the reported data. A brief description of the segment shall be included on graphs or tables of analysed results.

If the test segment is only a part of the actual work cycle of a work machine, then the curves or tables of analysed results for the test segment shall state the number of minutes or hours per typical 8 h day that the spectral data represents, considering what might be repeated daily over many years.

b) The road or terrain profile; as a minimum, details shall be given as to the type of surface (concrete roadway, compacted soil, cobblestone, profile track, in accordance with ISO 5008, for measuring vibration on agricultural tractors, etc.) and the condition of surface (new roadway, rutted road poorly maintained, etc.); a photograph of the road should be included.

c) If the road or terrain profile is measured, analysed and reported in spectral form, it shall be plotted as power spectral density in square metres per metre to the power of minus one ($m^2/m^{-1}$) versus spatial frequency in metres to the power of minus one on logarithmic scales. The graph shall include the information similar to that specified in clause 8.

NOTE — It is normally expected that the data will be taken in test conditions so that the data are statistically stationary (e.g. for conditions of constant speed and a statistically stationary road profile in the case of road vehicles).

# Annex

# Example method of reporting

(This annex does not form part of this standard.)

## A.1 General

This annex contains fictitious data arranged to form an example which meets the minimum requirements of this International Standard.

## A.2 Test site [see 9.3 a)]

**Table 2**

| Test segment | Points | Speed km/h | Slope % | Distance m | Surface [see 9.3 b)] |
|---|---|---|---|---|---|
| 1 | 1-2 | 50 | 0 | 4 000 | New, concrete roadway |
| 2 | 2-3 | 30 | + 3 | 4 400 | New, concrete roadway |
| 3 | 3-4 | 40 | 0 | 4 000 | Levelled, compacted earth and graded stone |
| 4 | 4-1 | 30 | − 3 | 4 400 | Levelled, compacted earth and graded stone |



Dimensions in metres

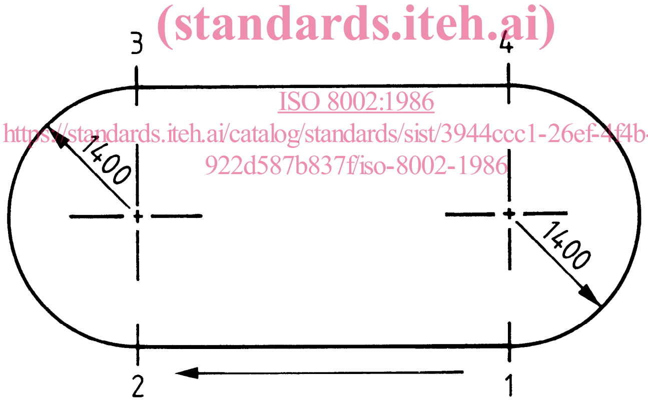



**Figure 1 — Test site**

## A.3 Vehicle data sheet

Vehicle [see 9.2 a)]: Automobile

Unladen mass [see 9.2 b)]: 1 450 kg

Wheelbase [see 9.2 b)]: 2 540 mm

Unique components [see 9.2 d)]: None

Tyre pressure [see 9.2 c)]: 170 kPa, all tyres

Mass distribution [see 9.2 c)]: Centre of gravity is 1 320 mm in front of, and 217 mm above, the rear axle centreline

Load [see 9.2 c)]: 75 kg driver

Occupant at interface [see 9.2 e)]: No interface measurement taken

Operating conditions (see 9.3): See test site plan and road profile power spectral density curves

## A.4 Instrumentation and data analysis

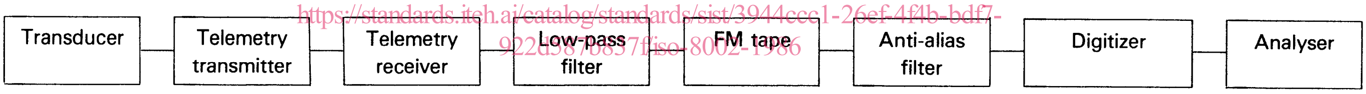
**Table 3**

| Instrumentation and parameters of analysis | Accelerometer location | | |
|---|---|---|---|
| | **Code A** | **Code B** | **Code C** |
| | **Vertical on left front wheel spindle** | **Lateral on left front wheel spindle** | **Vertical on left front frame** |
| Accelerometer | | | |
| Type [see 9.1 a)] | Tagmon SA: R21<br>Strain-gauge | Tagmon SA: R21<br>Strain-gauge | Tagmon SA: R21<br>Strain-gauge |
| Range [see 9.1 b)] | 100 m/s$^2$ | 100 m/s$^2$ | 100 m/s$^2$ |
| Natural frequency [see 9.1 b)] | 950 Hz | 950 Hz | 950 Hz |
| Frequency range, 5 % | 190 Hz | 190 Hz | 190 Hz |
| Sensitivity [see 9.1 b)] | 10 mV/ms$^{-2}$ | 10 mV/ms$^{-2}$ | 10 mV/ms$^{-2}$ |
| Accelerometer mounting [see 9.1 b)] | Bolted | Bolted | Bolted |
| System calibration [see 9.1 d)] | | | |
| Method | $2g$ roll-over | $2g$ roll-over | $2g$ roll-over |
| Span | $\pm 50$ m/s$^2$ | $\pm 25$ m/s$^2$ | $\pm 50$ m/s$^2$ |
| Record filter [see 9.1 e)] | 100 Hz low-pass | 100 Hz low-pass | 100 Hz low-pass |
| Analysis [see 8.1 a) and 8.3.a)] | FFT | FFT | FFT |
| Preprocessing filter [see 8.1 b)] | 24 dB/octave<br>32 Hz low-pass | 24 dB/octave<br>32 Hz low-pass | 24 dB/octave<br>32 Hz low-pass |
| Sample frequency [see 8.3 b)] | 64 s$^{-1}$ | 64 s$^{-1}$ | 64 s$^{-1}$ |
| Analysis range [see 8.3 c)] | 0 to 32 Hz | 0 to 32 Hz | 0 to 32 Hz |
| Sampling window [see 8.3 d)] | | | |
| Function | Hanning | Hanning | Hanning |
| Correction | 1,63 | 1,63 | 1,63 |



## A.5 Flow-chart of instrumentation [see 9.1 c)]






A dummy channel was used to detect spurious transients.

Transducer: Tagmon SA, model R21

Telemetry transmitter: Ashton Co., model 165

Telemetry receiver: Ashton Co., model 270

Low-pass filter: 100 Hz, 24 dB/octave

FM tape recorder: Veronti Co., model LT4

Anti-alias filter: 32 Hz low-pass, 24 dB/octave

Digitizer: Magner Inc., model MI

Analyser: Roenet, model 60