INTERNATIONAL STANDARD

ISO 8579-2

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Acceptance code for gears —

Part 2:
Determination of mechanical vibrations of gear units during acceptance testing

Code de réception des engrenages —

Partie 2: Détermination des vibrations mécaniques d'une transmission par engrenages au cours des essais de réception

Reference number
ISO 8579-2:1993(E)

Contents

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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.

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.

International Standard ISO 8579-2 was prepared jointly by Technical Committees ISO/TC 60, *Gears* and ISO/TC 108, *Mechanical vibration and shock*.

ISO 8579 consists of the following parts, under the general title *Acceptance code for gears*:

— *Part 1: Determination of airborne sound power levels emitted by gear units*

— *Part 2: Determination of mechanical vibrations of gear units during acceptance testing*

Annexes A, B, C, D and E of this part of ISO 8579 are for information only.

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Acceptance code for gears —

Part 2:
Determination of mechanical vibrations of gear units during acceptance testing

1 Scope

1.1 This part of ISO 8579 specifies the methods for determining mechanical vibration of individually housed, enclosed, speed-increasing and speed-reducing gear units. It specifies methods for measuring housing and shaft vibrations, and the types of instrumentation, measurement methods and testing procedures for determining vibration levels. Vibration grades for acceptance are included.

It does not include torsional vibration measurements of a geared system.

This part of ISO 8579 applies only to a gear unit under test and operating within its design speed, load, temperature range and lubrication for acceptance testing at the manufacturer's facility. The gear unit may be tested at another location if agreed upon and operated in accordance with the manufacturer's recommendations. Other International Standards on vibration evaluation may be required for measuring gear unit vibration in field service.

This part of ISO 8579 does not apply to special or auxiliary drive trains, such as integrated gear-driven compressors, pumps, turbines, etc., and power take-off gears.

NOTE 1 Acceptance limits for tests of these types of equipment should be independently specified. However, if negotiated, this or other appropriate standards may be applied to such equipment.

1.2 Special provisions may be required for vibration measurements: the type of measurement and acceptance level should therefore be agreed between the manufacturer and purchaser at an early stage of negotiation.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 8579. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8579 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

3 Definitions

For the purposes of this part of ISO 8579, the definitions given in ISO 2041, together with the following, apply. For the convenience of users of this part of ISO 8579, some definitions are quoted from ISO 2041:1990.

3.1 non-contact transducer: A transducer which converts a distance or displacement to an electrical signal that is proportional to the distance or displacement.

3.2 acceleration: A vector that specifies the time-derivative of velocity.

[ISO 2041, 1.3]

NOTE 2 See annex A.

3.3 displacement; relative displacement: A vector quantity that specifies the change of position of a body, or particle, with respect to a reference frame.

[ISO 2041, 1.1]

NOTE 3 See annex A.

3.4 frequency reponse: The output signal expressed as a function of the frequency of the input signal. The frequency response is usually given graphically by curves showing the relationship of the output signal and, where applicable, phase shift or phase angle as a function of frequency.

[ISO 2041, B.13]

3.5 peak-to-peak value (of a vibration): The algebraic difference between the extreme values of the vibration.

[ISO 2041, 2.35]

3.6 root-mean-square value; r.m.s. value: For a single-valued function $f(t)$ over an interval of time between t_1 and t_2, the square root of the average of the squared values over the interval.

NOTES

4 The r.m.s. value of a single-valued function $f(t)$ over an interval between t_1 and t_2 is

$$\text{r.m.s. value} = \left[\int_{t_1}^{t_2} f(t)^2 \mathrm{d}t / (t_2 - t_1) \right]^{1/2}$$

5 In vibration theory, the mean value of the vibration is equal to zero. In this case, the r.m.s. value is equal to the standard deviation (σ) and the mean-square value is equal to the variance (σ^2).

[ISO 2041, A.37]

3.7 transducer: A device designed to receive energy from one system and supply energy, of either the same or of a different kind, to another in such a manner that the desired characteristics of the input energy appear at the output.

[ISO 2041, 4.1]

3.8 velocity; relative velocity: A vector that specifies the time-derivative of displacement.

[ISO 2041, 1.2]

NOTE 6 See annex A.

3.9 vibration: The variation with time of the magnitude of a quantity which is descriptive of the motion or position of a mechanical system, when the magnitude is alternately greater and smaller than some average value or reference.

[ISO 2041, 2.1]

4 General

4.1 System considered

The gear unit should be tested in such a manner as to minimize as far as possible effects of the system (see annex B).

4.2 Effects of system

Vibration levels of the gear unit in field service may be adversely affected by factors beyond the control of the gear manufacturer, as listed in annex B. It is preferable to estimate the vibration of the whole system and to check the system effects at the initial design stage of a transmission system. The responsibility for checking should be clearly defined during this stage and all interested parties made aware of the decision.

4.3 Housing or shaft measurements

The vibrations of a gear unit can be measured in two ways, i.e. on the housing or on the shafts. Housing vibration measurements are preferred for gear units operating with rolling contact bearings when the clearance in such bearings is small and little relative movement normally occurs between the shaft and housing.

Both shaft and housing vibration measurements may be made on gear units operating with plain journal bearings. Shaft vibration measurements can provide detailed information which may not be evident from housing measurements, but only over a limited frequency range (typically 0 Hz to 500 Hz). Housing vibration measurements have the advantage of having both an extended frequency range and an extended dynamic range which are essential when considering frequency of tooth contact. See the provisions of 1.2.

Care shall be taken when choosing the measurement instrument for a given gear unit and operating conditions, as each instrument has its own characteristics (see annex C). It is often useful to combine both shaft and housing vibration measurements to obtain an absolute motion of the gear unit shaft.

When operating conditions during acceptance testing deviate considerably from field service, the differences shall be taken into account in the assessment of vibration data.

5 Instrumentation

5.1 Type

Vibration shall be measured using a transducer and an instrument with a known accuracy for the measurement of velocity and displacement across a known frequency range. The instrument shall also have an electrical output signal of known accuracy related to velocity or displacement, or both. The transducer shall be used within its calibrated limits for the mounting method and for the prevailing environmental conditions such as temperature, magnetic field, surface finish, etc. The type and use of vibration instrumentation systems shall comply with the appropriate International Standards. The instrumentation should preferably include a facility for narrow-band frequency analysis with a bandwidth not exceeding one-third-octave.

5.1.1 Shaft measurement instrumentation

The recommended type of transducer for measuring shaft vibration is a non-contacting transducer. The instrument shall allow a reading of peak-to-peak values of vibration displacement to be taken. However, contacting transducers are acceptable if the rotational frequency of the shaft is less than 3 000 min^{-1}, the signal frequency is less than 200 Hz, and surface rubbing velocity is less than 30 m/s.

5.1.2 Housing measurement instrumentation

The recommended type of transducer for measuring housing vibration is a seismic transducer. The equipment shall include an electrical instrument with a true r.m.s. rectification characteristic giving the r.m.s. values of vibration velocity in millimetres per second. The mounting method can affect the frequency response of the transducer; it should therefore be mounted with a screw or stud, or using bonding material. Magnetic mounting using lightweight accelerometers, may be acceptable for frequencies up to 3 000 Hz if the highest fundamental frequency of tooth meshing is less than 1 000 Hz. Hand-held contact measurements are not acceptable.

5.2 Measurement frequency range

The instrument measurement frequency range shall be capable of measuring the lowest shaft rotational speed and the highest tooth mesh frequency. The shaft displacement frequency measurement range should be between 0 Hz and 500 Hz. The housing velocity frequency measurement range when using integrated acceleration measurements should preferably be between 10 Hz and 10 000 Hz or more.

5.3 Permissible error

The measuring instrumentation system, including both the transducer and read-out instrumentation shall be capable of indicating the vibration level within a permissible error of 10 % of the reading over the entire operating temperature range.

5.4 Calibration

The vibration read-out instrumentation shall be checked against a reference signal and any specified adjustments made immediately before and rechecked immediately after each series of gear unit vibration measurements.

Calibrations of the complete measuring equipment should be carried out at least once every 2 years.

6 Vibration measurements

6.1 Shaft measurements

Vibration displacement of the shafts should preferably be measured relative to the housing. Non-contacting transducers should be used, located as near to a bearing as possible and attached to rigid housing sections. Shaft vibration shall be measured in three orthogonal directions (mutually perpendicular axes), one of which shall be parallel to the shaft axis. Only one such axial transducer per shaft is necessary. The number and location of transducers shall be agreed upon between the purchaser and manufacturer.

The mechanical and electrical run-out should preferably not exceed 25 % of the allowable vibration displacement at the shaft rotational frequency, or 6 µm, whichever is the greater. Shaft mechanical and electrical run-out at the transducer locations may be subtracted from the vibration readings to give the actual vibration levels, provided the vector and phase relationships are maintained between the run-out and the shaft vibration measurement. The permissible error in the actual vibration measurement for such subtraction shall not exceed that specified in 5.3.

6.2 Housing measurements

Housing vibration shall be measured on a rigid housing section such as a bearing block. Measurements shall not be made on housing sections which do not support the bearings since they are not indicative of gear unit performance. Measurements shall be taken in three orthogonal directions, two of which lie in a plane perpendicular to the rotating axis of the gears, preferably horizontal and vertical. It is recommended that measurements be taken at each externally accessible bearing location on a gear unit. If a bearing block is inaccessible, then the nearest mounting point may be used. The number and location of transducers depend upon the rigidity of the housing and on the number of shafts and shall be agreed between the purchaser and manufacturer.

6.3 Units of measurement

The acceptable units of measurement are given in table 1.

Table 1

Quantity	Unit
Velocity (r.m.s.)	mm/s dB (reference: $v_0 = 5 \times 10^{-5}$ mm/s)
Displacement (peak-to-peak)	µm
Frequency	Hz

7 Testing

The measurement of vibration on a gear unit should be conducted during the manufacturer's shop test. The system of test transmission shall be at the manufacturer's option unless otherwise negotiated with the purchaser.

7.1 Arrangement of test system

The test transmission, driver, gear unit and any load shall be connected by the in-service couplings or by couplings with similar effective overhung masses.

7.2 Test conditions

The conditions given in 7.2.1 to 7.2.5 shall apply, unless agreed otherwise between the gear manufacturer and purchaser.

7.2.1 The gear unit shall be tested at its intended operating speed or, if designed for variable-speed service, at the arithmetic mean of its speed range.

7.2.2 The gear unit shall be tested in its intended direction of rotation or, if reversible, in both directions.

7.2.3 The gear units shall be tested without load or with a light load to stabilize operation.

7.2.4 The test measurements shall be carried out using the operating lubricating system and the lubricant viscosity corresponding to the operating viscosity.

7.2.5 Vibration measurement shall be carried out when the machinery is operating within its design temperature range.

8 Acceptance values

A rating system for shaft displacement and housing velocity measurements is shown in figures 1 and 2 to form a common basis for comparison. The acceptable rating for a given application should be chosen from the figures and based on instrumentation agreed upon between the manufacturer and purchaser at an early stage of negotiation. Acceptance can be established from either a single criterion for the entire gear unit or separate criteria for each shaft or measuring position. Annex D gives subjective vibration ratings for typical gear unit applications.

8.1 Vibration amplitude

Vibration characteristics are plotted against frequency in figures 1 and 2. It is important to note that filtered measurements were used to draw up these figures. Several components of vibration at different frequencies may acceptably exist at the same time, each one at the allowable limit for that frequency as determined from the curves. Equipment capable of frequency analysis is required for this purpose. Care shall be taken to ensure that this equipment can resolve the vibration into individual component frequencies so that a legitimate comparison can be made with the figures.

8.1.1 Frequency bandwidth

It is important to note that the bandwidth of various instruments such as a one-third-octave or Fast Fourier Transform analyser may show a higher or lower value depending upon the frequency of a given band and the amount of random vibration.

8.1.2 Overall value

If frequency spectrum data are not obtainable or not known, one or both of the following methods may be used to provide an indication of acceptability:

a) the test result is acceptable if the nominal value of the unfiltered housing velocity does not exceed the maximum of the velocity grade (see figure 2);

b) a nominal unfiltered shaft displacement value is taken from figure 1 using the shaft rotational speed as the discrete frequency of the grade.

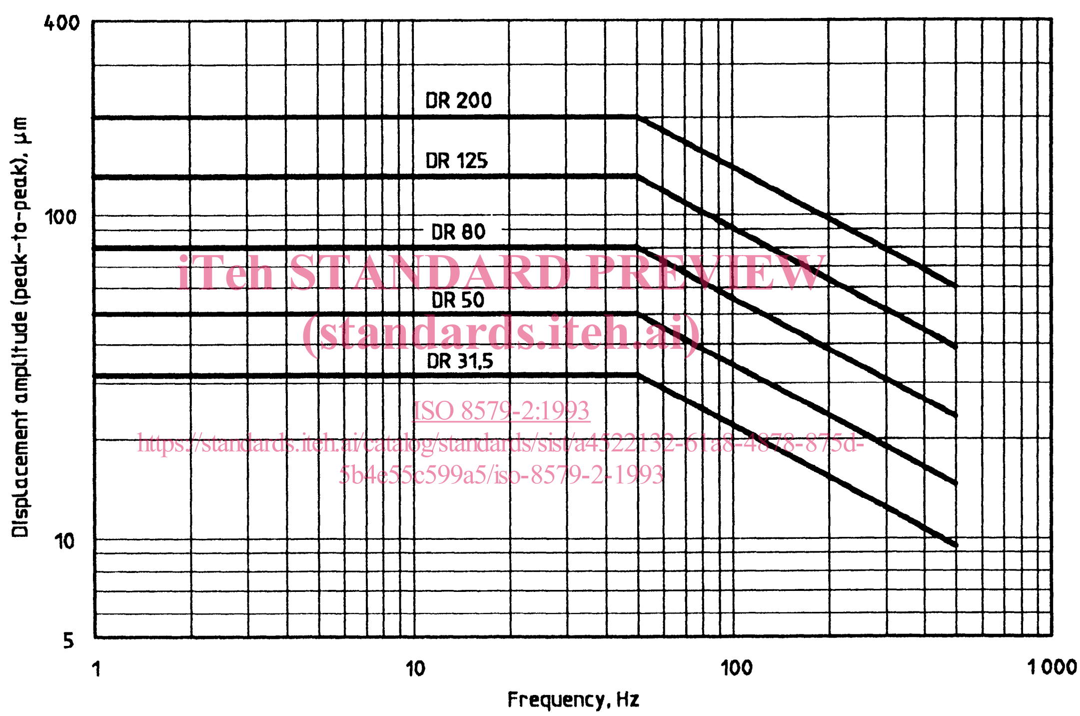
NOTE 7 The provisions of subclause 1.2, that "the type of measurement and acceptance level should therefore be agreed between the manufacturer and purchaser at an early stage of negotiation", apply for overall value or frequency bandwidth acceptance.[1)]

8.2 Rating of measured shaft displacements

Peak-to-peak values of shaft displacement may be rated using figure 1. The rating of a gear shaft shall be based on the lowest line enclosing all the measured filtered shaft displacements. A particular gear unit shall be given the highest rating measured on all the shafts monitored.

8.3 Rating of measured housing vibration

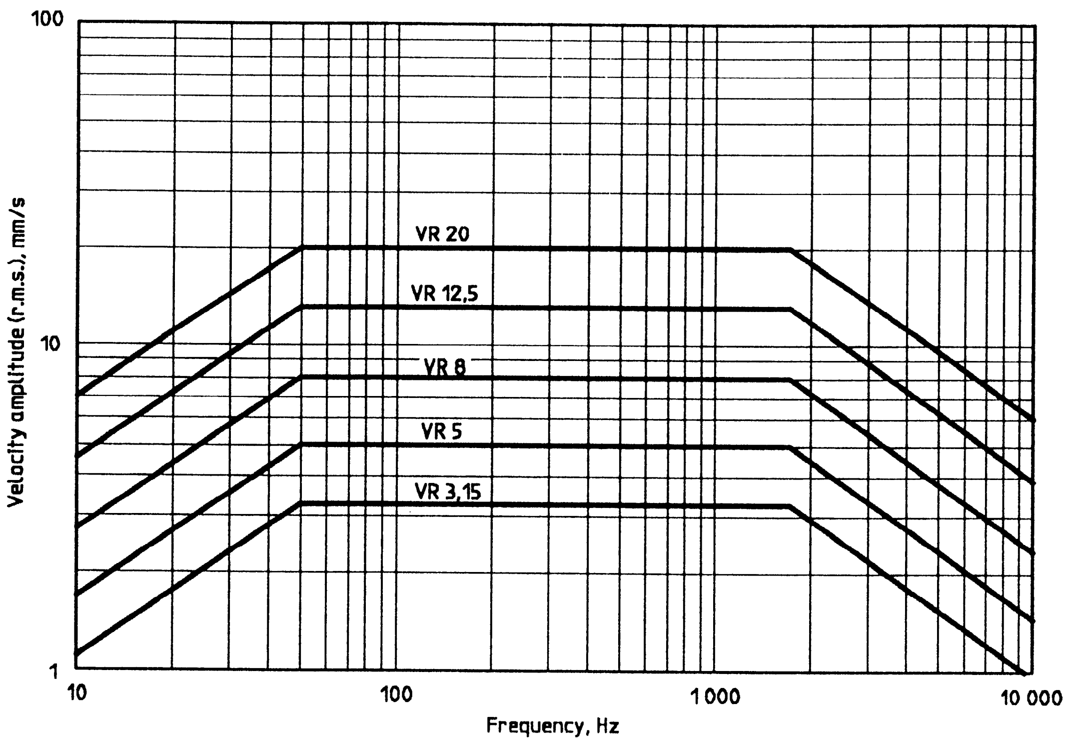
R.m.s. values of housing vibration velocity may be rated by comparison with figure 2. The rating of a given measuring position shall be based on the lowest line fully enclosing its complete vibration spectrum. A particular gear unit shall be given the highest rating measured from all the positions monitored.



NOTE — The rating number is equivalent to the displacement of the rating curve between 0 Hz and 50 Hz. Above 50 Hz, the curves decrease by 10 dB per decade.

Figure 1 — Rating curves for shaft vibration

1) The use of a value from figure 1 or 2 for an overall (unfiltered) acceptance, in place of filtered measurements, reduces the allowable vibration (increases the vibration rating of the gear unit), unless it is known that the vibration is predominantly due to one or two major frequency components.



NOTE — The rating number is equivalent to the velocity of the rating curve between 45 Hz and 1 590 Hz. The curves decrease from 45 Hz and 1 590 Hz at 14 dB per decade.

Figure 2 — Rating curves for housing vibration

9 Test report

The test report shall include the information specified in 9.1 to 9.5.

9.1 Manufacturer

Type and definition of the gear unit investigated.

9.2 Operating data

Test operating data, conditions for setting-up and running the gear unit, including mounting and coupling characteristics.

Special attention shall be drawn to any deviation from the conditions specified in 7.1 and 7.2.

9.3 Description of arrangement

Descriptions (including dimensional sketch of the arrangement of the gear unit), position, axis and data from individual measurement points in accordance with 6.1 and 6.2.

9.4 Measuring equipment

List of all measuring equipment used, by make and type.

9.5 Test measurements and results

Test measurements and results shall include one or more of the following for each measurement position:

a) overall vibration values;

b) major vibration frequency components and their amplitude;

c) narrow-band frequency spectra.

A fluctuating meter reading shall be recorded as a subjective average.

Annex A
(informative)

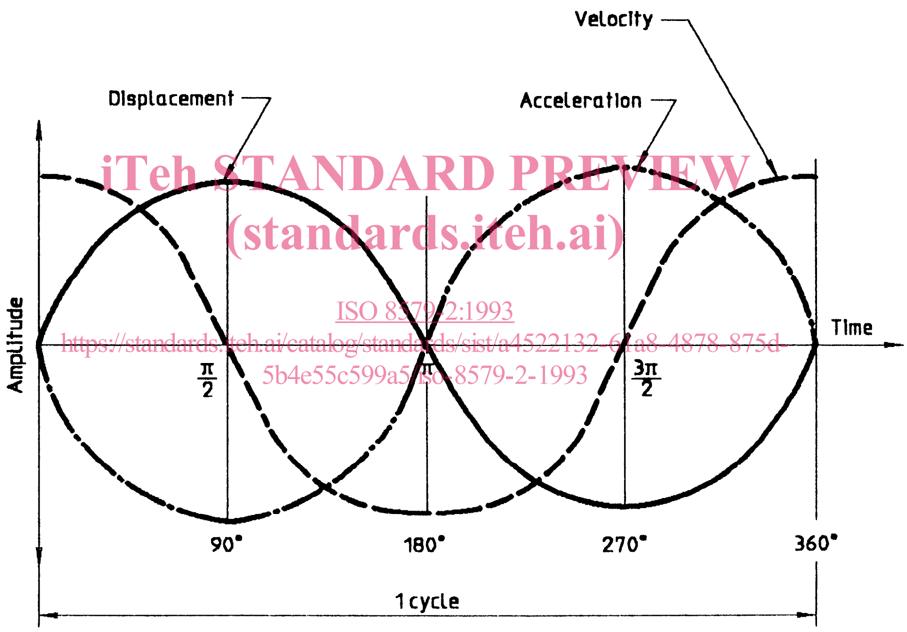
Relationship between displacement, velocity and acceleration waveforms

A.1 Purpose

This annex outlines the relationship between displacement, velocity and acceleration waveforms.

A.2 Waveform relationship

Any vibration of periodic sinusoidal waveform can be defined in terms of displacement, velocity and acceleration amplitude at an appropriate frequency. Velocity is the first differential of displacement and acceleration is the second differential (with respect to time). See figure A.1.



Displacement $D = A \sin(\omega t)$

Velocity $v \left(= \frac{dD}{dt} \right) = \omega A \cos(\omega t)$

Acceleration $a \left(= \frac{dv}{dt} \right) = -\omega^2 A \sin(\omega t)$

where

t is the time;

ω is the circular frequency (in this case, $\omega = 1$);

A is the amplitude.

NOTE — Note that, as a function of time, velocity and acceleration lead displacement by $\pi/2$ (= 90°) and π (= 180°) respectively.

Figure A.1 — Waveform