

BS ISO 10816-8:2014



BSI Standards Publication

# Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts

Part 8: Reciprocating compressor systems

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## National foreword

This British Standard is the UK implementation of ISO 10816-8:2014.

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

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# ISO 10816-8

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## Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

### Part 8: Reciprocating compressor systems

*Vibrations mécaniques — Évaluation des vibrations des machines par  
mesurages sur les parties non tournantes —*

*Partie 8: Systèmes de compresseurs alternatifs*



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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures* in collaboration with ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

- *Part 1: General guidelines*
- *Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1500 r/min, 1800 r/min, 3000 r/min and 3600 r/min*
- *Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ*
- *Part 4: Gas turbine sets with fluid-film bearings*
- *Part 5: Machine sets in hydraulic power generating and pumping plants*
- *Part 6: Reciprocating machines with power ratings above 100 kW*
- *Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts*
- *Part 8: Reciprocating compressor systems*
- *Part 21: Horizontal axis wind turbines with gearbox*

## Introduction

ISO 10816-1 gives general guidelines for the evaluation of machine vibration by measurements on non-rotating parts. This part of ISO 10816, however, establishes special procedures and guidelines for the measurement and classification of mechanical vibration of reciprocating compressors. In general, it refers to vibration of the main structure of the compressor, including the foundation, pulsation dampers, and attached pipe system. The guidance values given for these vibrations are defined primarily to classify the vibration and to avoid problems with auxiliary equipment mounted on these structures. Recommendations for measurements and evaluation criteria are provided in this part of ISO 10816.

Typical features of reciprocating compressors are the oscillating masses, the cyclically varying torques, cylinder stretch and the pulsating forces in the cylinders, pulsation dampers, and the pipe system. All these features cause alternating loads on the main supports and vibration of the compressor system. The vibration values of reciprocating compressor systems are generally larger than for rotating compressors but, since they are largely determined by the design features of the compressor, they tend to remain more constant over the life of the system than for rotating machinery.

In the case of reciprocating compressor systems, the vibration measured on the main structure of the compressor (including the foundation, pulsation dampers and piping) and quantified according to this part of ISO 10816 can only give a rough idea of the vibratory states of the components within the machine itself.

The damage, which can occur when exceeding the guidance values based on experience with similar compressor systems, is sustained predominantly by machine-mounted components (e.g. instrumentation, heat exchangers, filters, pumps), connecting elements of the compressor with its peripheral parts (e.g. pipelines) or monitoring instruments (e.g. pressure gauges, thermometers). The question as to which vibration values damage is to be expected largely depends on the design of these components and their fastenings. In some cases, special measurements on certain compressor system components can be required to ascertain that the vibration values do not cause damage. It also happens that even if measured values are within the guidance values of this part of ISO 10816, problems can occur owing to the great variety of components which can be attached.

Local vibration problems as described above can be, and have to be, rectified by specific “local measures” (e.g. by elimination of resonances). Experience has shown, however, that it is possible in the majority of cases to state measurable quantities characterizing the vibratory state and to give guidance values for these. This shows that the measurable variables and the guidance values for acceptable vibration in most cases permit a reliable evaluation.

If the measured vibration values as given in this part of ISO 10816 do not exceed the guidance values, abnormal wear of internal compressor components caused by vibration is unlikely to occur.

The vibration values of reciprocating compressor systems are not only affected by the properties of the compressor itself but also to a large degree by the foundation. Since a reciprocating compressor can act as a vibration generator, vibration isolation between the compressor and its foundation can be necessary. The vibration response of the foundation and the vibration from adjacent equipment can have considerable effect on the vibration of the compressor system.





# Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

## Part 8: Reciprocating compressor systems

### 1 Scope

This part of ISO 10816 establishes procedures and guidelines for the measurement and classification of mechanical vibration of reciprocating compressor systems. The vibration values are defined primarily to classify the vibration of the compressor system and to avoid fatigue problems with parts in the reciprocating compressor system, i.e. foundation, compressor, dampers, piping, and auxiliary equipment mounted on the compressor system.

This part of ISO 10816 applies to reciprocating compressors mounted on rigid foundations with typical rotational speed ratings in the range 120 r/min up to and including 1 800 r/min. The general evaluation criteria which are presented relate to operational measurements. The criteria are also used to ensure that machine vibration does not adversely affect the equipment directly mounted on the machine, e.g. pulsation dampers and the pipe system.

**NOTE** The general guidelines presented in this part of ISO 10816 can also be applied to reciprocating compressors outside the specified speed range but different evaluation criteria might be appropriate in this case.

The machinery driving the reciprocating compressor, however, is evaluated in accordance with the appropriate part of ISO 10816 or other relevant standards and classification for the intended duty. Drivers are not included in this part of ISO 10816.

It is recognized that the evaluation criteria might only have limited application when considering the effects of internal machine components, e.g. problems associated with valves, pistons, and piston rings might be unlikely to be detected in the measurements. Identification of such problems can require investigative diagnostic techniques which are outside the scope of this part of ISO 10816.

Examples of reciprocating compressor systems covered by this part of ISO 10816 are

- horizontal, vertical, V-, W-, and L-type compressor systems,
- constant and variable speed compressors,
- compressors driven by electric motors, gas, and diesel engines, steam turbines, with or without a gearbox, flexible or rigid coupling, and
- dry running and lubricated reciprocating compressors.

This part of ISO 10816 does not apply to hyper compressors.

The guidelines are not intended for condition monitoring purposes. Noise is also outside the scope of this part of ISO 10816.

### 2 Normative references

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

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 and the following apply.

#### 3.1 compressor system

machinery system comprising foundation, compressor (crankcase, crosshead guide, cylinders), pulsation dampers, and piping

#### 3.2 overall vibration value

single numeric representation of a feature or aggregate of features derived from a raw or processed time waveform or frequency spectrum of a vibration signal and often accompanied by descriptive text or indicators to specify methods used in its derivation

Note 1 to entry: The overall vibration value is measured in the frequency range from 2 Hz to 1 000 Hz.

#### 3.3 corner frequency

frequency used to convert the vibration displacement to vibration velocity and vibration velocity to vibration acceleration for a sinusoidal signal

Note 1 to entry: The corner frequencies are 10 Hz and 200 Hz, respectively.

#### 3.4 vendor

manufacturer or manufacturer's agent who supplies the compressor system

#### 3.5 purchaser

agency that issues the order and specification to the vendor

## 4 Measurements

### 4.1 Measurement procedure

The primary measurement quantity shall be overall root-mean-square (r.m.s) vibration velocity in mm/s.

If frequencies below the corner frequency of 10 Hz are expected or observed, it is recommended additionally to measure the overall r.m.s vibration displacement in mm (it is also common to display displacement in micrometres where  $1 \mu\text{m} = 10^{-3} \text{ mm}$ ).

If frequencies above the corner frequency of 200 Hz are expected or observed, it is recommended additionally to measure the overall r.m.s vibration acceleration in  $\text{m/s}^2$  (it is still common, but not recommended, to display acceleration in units of  $g$  where  $g = 9,81 \text{ m/s}^2$ ).

NOTE The relationship between displacement, velocity, and acceleration is given in [B.1](#).

Consequently, and in accordance with ISO 10816-1, acceptance criteria based on velocity take the general form of [Figures B.1](#) to [B.10](#). These figures indicate the corner frequencies of 10 Hz and 200 Hz and show that below and above these corner frequencies, the guidance vibration velocity is a function of vibration frequency.

All values shall be within the values for acceptable overall vibration as summarized in [5.3](#).

Spectral data should be retrieved for each of the measured quantities if they exceed the vibration values of evaluation zone boundary B/C as defined in [5.2](#) to aid in analysis and possible correction.

Vibration acceleration values are often measured to carry out condition monitoring of internal compressor components. However, this part of ISO 10816 is not intended to be applied for condition monitoring purposes. For example, if the condition of the compressor valves is to be monitored, other procedures and standards with different values can apply. The vibration acceleration values given in this part of ISO 10816 should, therefore, only serve as a criterion to judge the overall integrity of the compressor system and attached equipment, e.g. pressure and/or temperature transmitters and valve-lifting devices. When the acceleration values given in this part of ISO 10816 are exceeded, this does not, by definition, imply that corrective actions are required. The susceptibility of components to large acceleration values (instruments, heavy components on small equipment nozzles, etc.), the presence of audible noise or knocking sounds, or unusual or sudden changes of vibration values should then become a point of attention and further analysis.

Furthermore, it should be kept in mind that the measured acceleration values on locations as shown in [Figures 1 to 5](#) are not the values of the attached equipment but the values of the compressor system parts (foundation, crankcase, cylinder, dampers, and piping) to which they are mounted.

## 4.2 Measuring instrumentation and measured quantities

Criteria for classifying vibration values for reciprocating compressor systems are specified in [Clause 5](#). It is recognized that the main excitation frequencies for reciprocating compressor systems are generally found in the range 2 Hz to 300 Hz. However, when considering the complete compressor system, including auxiliary equipment that is a functional part of the compressor, a typical range of 2 Hz to 1 000 Hz is applied to characterize the overall vibration. For the purposes of this part of ISO 10816, the overall r.m.s vibration value shall represent vibration across the frequency range from 2 Hz to 1 000 Hz. For special purposes, a different range can be agreed between the vendor and purchaser.

Since the overall vibration signal usually contains many frequency components, there is no simple mathematical relationship between the r.m.s, peak, or peak-to-peak overall vibration measurements, see [Annex D](#).

The measuring system should provide the r.m.s values of displacement, velocity, and acceleration with an accuracy of  $\pm 10\%$  over the range 10 Hz to 1 000 Hz and with an accuracy of  $+10\%$  and  $-20\%$  over the range 2 Hz to 10 Hz. These values can be obtained from a single transducer whose signal is processed to derive the quantities not directly measured, preferably an accelerometer whose output is integrated once for velocity and twice for displacement. ISO 2954 gives requirements for instruments for measuring vibration severity. Guidelines on applying methods of signal processing and display, e.g. time and frequency domain, windowing, and averaging, are covered in ISO 13373-2 and ISO 18431-1 and common examples are given in ISO 18431-2.

Care should be taken to ensure that any processing does not adversely affect the required accuracy of the measuring system. Both the frequency response and measured vibration values are affected by the method of attachment of the transducers. It is especially important to maintain a good attachment between the transducer and the compressor when the vibration velocities and frequencies are high. ISO 5348 gives guidelines on the mounting of accelerometers.

NOTE The guidance vibration values are not applicable for ovalling shell modes of pulsation dampers and large diameter pipe systems.

## 4.3 Locations and direction of measurements

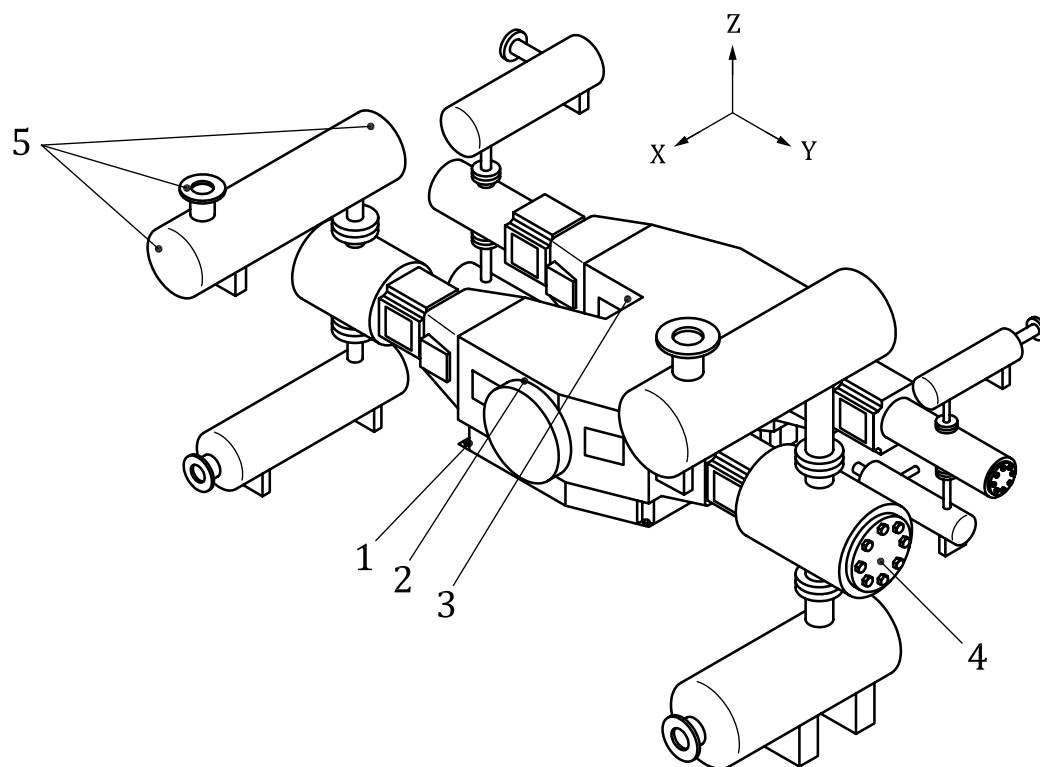
### 4.3.1 Locations

As a minimum, the vibration measurements shall be carried out on the locations shown in [Figures 1 to 5](#) as follows:

- foundation: at all compressor frame bolt locations;
- frame (top): on each corner point and between all cylinders for a compressor with more than two cylinders, all at the top of the frame;

- cylinders (lateral and rod): at the rigid part of each cylinder cover flange;
- pulsation vessels: at the inlet and/or outlet pipeline flange and at the heads;
- piping: at all critical parts of the system, to be determined by inspection and in agreement with the purchaser.

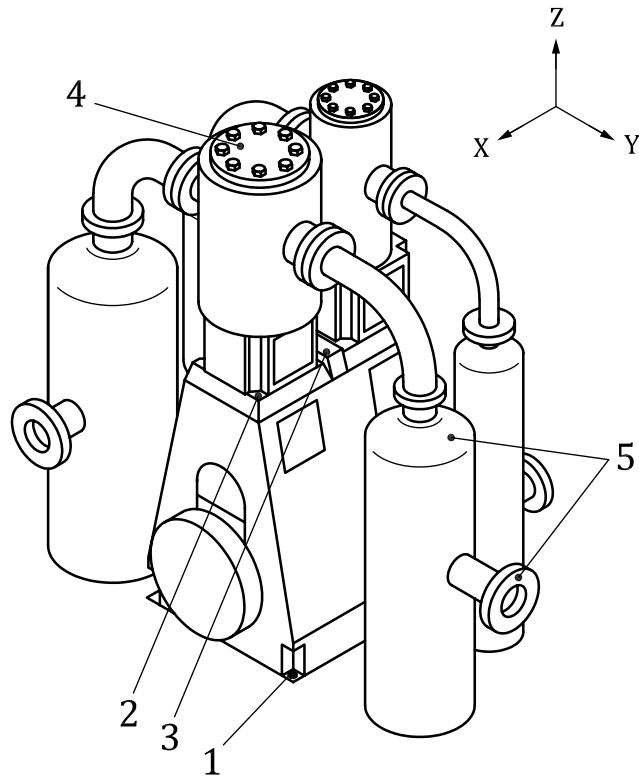
NOTE Accelerometers are often mounted on the crosshead guide for condition monitoring purposes of internal parts of the compressor. The vibrations are measured in the direction of the force exerted by the crosshead on this guide, which is in vertical direction of a horizontal compressor. Experience on horizontal compressors has shown that the vibration values measured on the crossheads guide can be used in addition to the vibration values of other locations to judge the integrity of the compressor. The procedures for measuring the vibration values on the crosshead guide are summarized in [Annex C](#).



- Key**
- 1 all compressor frame bolt locations
  - 2 each frame corner point
  - 3 each frame location between the cylinders (required for a compressor with more than one cylinder)
  - 4 each cylinder (cover flange at rigid location)
  - 5 pulsation vessels (only shown for one vessel in the figure)

NOTE The numbers apply to all types of these compressors (for clarity, only one point is shown in the figure for most of the locations). Piping is not shown in the figure, so point 6 should be agreed upon with the vendor. A detailed description of the directions is given in [4.3.2](#).

**Figure 1 — Measuring locations for a horizontal compressor**

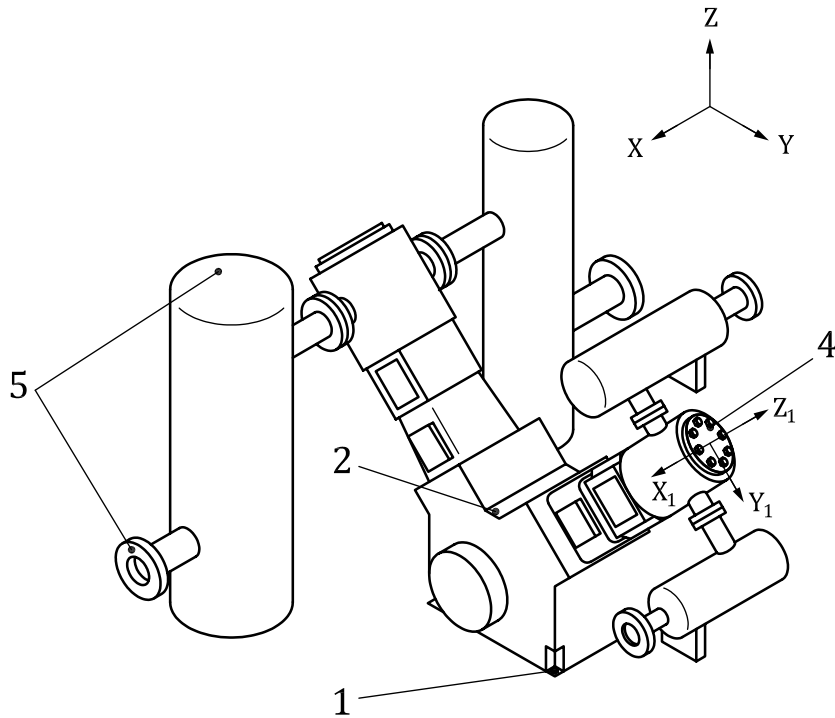


**Key**

- 1 all compressor frame bolt locations
- 2 each frame corner point
- 3 each frame location between the cylinders (required for a compressor with more than one cylinder)
- 4 each cylinder (cover flange at rigid location)
- 5 pulsation vessels (only shown for one vessel in the figure)

NOTE The numbers apply to all types of these compressors (for clarity only one point is shown in the figure for most of the locations). Piping is not shown in the figure, so point 6 should be agreed upon with the vendor. A detailed description of the directions is given in [4.3.2](#).

**Figure 2 — Measuring locations for a vertical compressor**

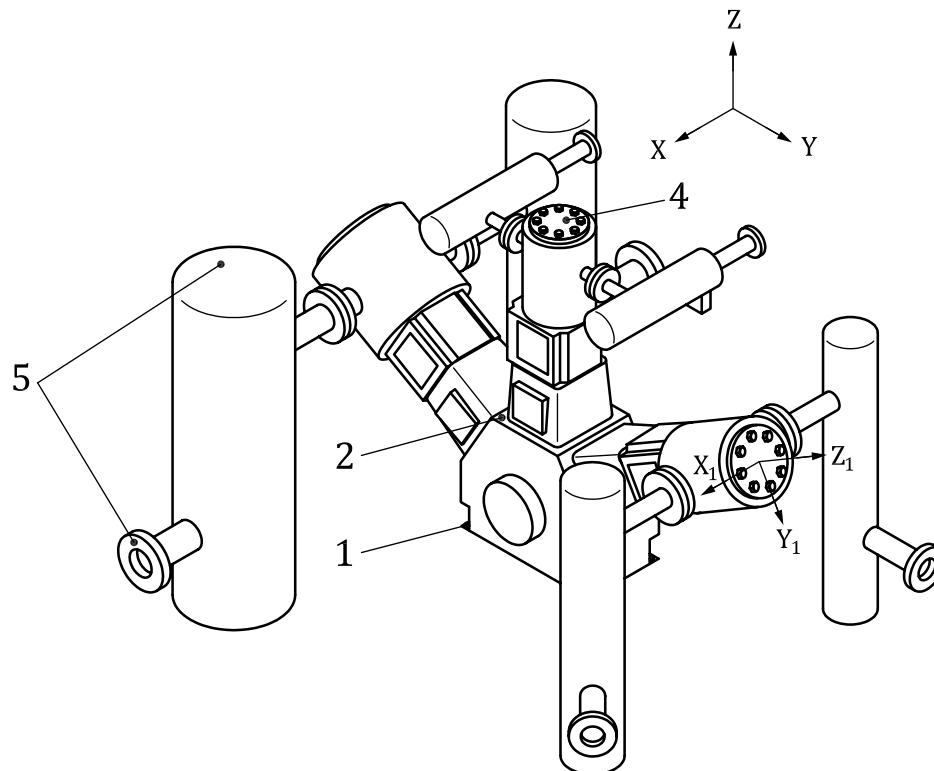


**Key**

- 1 all compressor frame bolt locations
- 2 each frame corner point
- 3 each frame location between the cylinders (required for a compressor with more than two cylinders)
- 4 each cylinder (cover flange at rigid location)
- 5 pulsation vessels (only shown for one vessel in the figure)

**NOTE** The numbers apply to all types of these compressors (for clarity only one point is shown in the figure for most of the locations). Piping is not shown in the figure, so point 6 should be agreed upon with the vendor. A detailed description of the directions is given in [4.3.2](#).

**Figure 3 — Measuring locations for a V-type compressor**

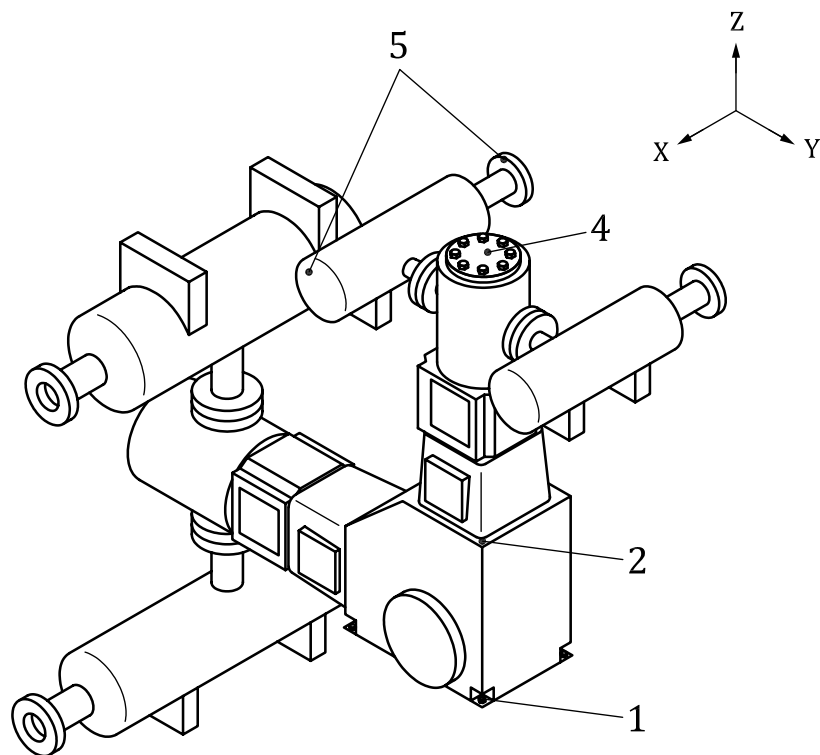


**Key**

- 1 all compressor frame bolt locations
- 2 each frame corner point
- 3 each frame location between the cylinders (required for a compressor with more than three cylinders)
- 4 each cylinder (cover flange at rigid location)
- 5 pulsation vessels (only shown for one vessel in the figure)

**NOTE** The numbers apply to all types of these compressors (for clarity only one point is shown in the figure for most of the locations). Piping is not shown in the figure, so point 6 should be agreed upon with the vendor. A detailed description of the directions is given in [4.3.2](#).

**Figure 4 — Measuring locations for a W-type compressor**



#### Key

- 1 all compressor frame bolt locations
- 2 each frame corner point
- 3 each frame location between the cylinders (required for a compressor with more than two cylinders)
- 4 each cylinder (cover flange at rigid location)
- 5 pulsation vessels (only shown for one vessel in the figure)

NOTE The numbers apply to all types of these compressors (for clarity only one point is shown in the figure for most of the locations). Piping is not shown in the figure, so point 6 should be agreed upon with the vendor. A detailed description of the directions is given in [4.3.2](#).

**Figure 5 — Measuring locations for an L-type compressor**

#### 4.3.2 Direction of measurements

The measurements should be carried out in the following directions.

a) Horizontal compressor:

- foundation, frame, cylinder, pulsation dampers, and piping: three mutually perpendicular X, Y, and Z directions as indicated in [Figure 1](#);

b) Vertical compressor:

- foundation, frame, cylinder, pulsation dampers, and piping: three mutually perpendicular X, Y, and Z directions as indicated in [Figure 2](#);

c) V-type compressor:

- foundation, frame, pulsation dampers, and piping: three mutually perpendicular X, Y, and Z directions as indicated in [Figure 3](#),
- cylinder: three mutually perpendicular X1 (perpendicular to cylinder), Y1 (perpendicular to cylinder), and Z1 (rod direction) directions as indicated in [Figure 3](#);



d) W-type compressor:

- foundation, frame, and pulsation dampers and piping: three mutually perpendicular X, Y, and Z directions as indicated in [Figure 4](#),
- cylinder: three mutually perpendicular X1 (perpendicular to cylinder), Y1 (perpendicular to cylinder), and Z1 (rod direction) directions as indicated in [Figure 4](#);

e) L-type compressor:

- foundation, frame, cylinder, pulsation dampers, and piping: three mutually perpendicular X, Y, and Z directions as indicated in [Figure 5](#).

#### 4.4 Operating conditions

Measurements should be taken when the compressor has reached its steady-state operating conditions (e.g. normal operating temperature). The determination of the vibration values shall be based on the maximum vibration values occurring over the entire speed range, if applicable, for all operating process conditions (e.g. different pressures, temperatures), specified alternative gases (e.g. N<sub>2</sub> for start-up), unloading conditions, single and multiple compressors in service, etc.

The structure on which the compressor is mounted, either concrete or skid, should not be in resonance. Operation at or near resonance should be avoided.

#### 4.5 Record of measured results

Records of all measured results should include essential data of the compressor system and of the measuring systems used (see [Annex A](#)).

### 5 Vibration criteria

#### 5.1 Measuring quantities

The maximum vibration values for overall vibration displacements, vibration velocities, and vibration accelerations shall be represented as r.m.s quantities.

#### 5.2 Evaluation zones

##### 5.2.1 General

The following evaluation zones are defined to permit a qualitative assessment of the vibration on a given compressor system and to provide guidelines on possible actions. Numerical values assigned to the zone boundaries are primarily intended to serve as guidance values and are not intended to serve as a final acceptance criterion. The guidance values for acceptable vibration are intended to ensure that gross deficiencies or unrealistic requirements are avoided. In certain cases, there can be specific features associated with a particular compressor system which would require different boundary values (smaller or larger) to be used, which should be agreed between the vendor and purchaser. In such cases, it is normally necessary to clarify the reasons for this and, in particular, to confirm that the compressor system will not be endangered by operating with larger vibration values.

**Zone A, zone B:** Compressor systems with vibration within these zones are normally considered acceptable for long-term operation.

**Zone C:** Compressor systems with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the compressor can be operated for a limited period in this condition until a suitable opportunity arises for remedial action such as analysis and possible correction. Clarify between the vendor and the purchaser that the compressor is suitable for long-term safe operation.

**Zone D:** Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the compressor and attached equipment.

Transitions for the zone boundaries for reciprocating compressor systems are summarized in [Table 1](#).

**Table 1 — Evaluation zone descriptions**

Zone	Range	Criterion	Description (See Notes)
A	$\leq A/B$	Acceptable	Compressor systems with vibration within these zones are normally considered acceptable for long-term operation.
B	$> A/B$ and $\leq B/C$		
C	$> B/C$ and $\leq C/D$	Marginal	Analysis and possible correction to be undertaken. Clarify between the vendor and the purchaser that the compressor is suitable for long-term safe operation.
D	$> C/D$	Unacceptable	Urgent correction to be performed or shutdown to be considered (see Note 3).

NOTE 1 These guidance values are not applicable to test bed conditions. Test bed conditions are unlikely to represent *in situ* conditions due to variations in foundation flexibility, fixings and supports, loading, flow, gas conditions, resonances, piping, valves, vessels, etc. For test bed conditions, other values might need to be applied based on the compressor OEM's experience and in agreement with the purchaser.

NOTE 2 Zone B is included to define the range A/B to B/C. It can be used as an engineering reference. Field measurements taken on mainly low-speed, constant process-condition machines are centred around the zone boundary A/B.

NOTE 3 If the vibration velocity of the main pipe system exceeds the appropriate C/D vibration value (zone D), this does not, by definition, mean that a fatigue failure in the main piping will occur. Fatigue failures often occur in small bore piping and attached equipment to the main piping, e.g. pressure and temperature transmitters or drains. For that reason, consideration to shut down the system is not necessary if all of the following is fulfilled.

- The maximum vibration velocity in the piping does not exceed an r.m.s value of 45 mm/s.
- There are no small bore piping and equipment attached to the main pipe system which have large vibration velocity values.
- Vibration displacement values of the main piping are smaller than the defined values of zone boundary C/D.
- Analysis of the relevant pipe section shows that a fatigue failure is not likely to occur, e.g. by analytical methods, finite element analysis, modelling, or strain gauge measurement.
- Acceptance for long-term operation shall be agreed upon between the vendor and the purchaser.
- Vibrations in zone D are commonly caused by the excitation of mechanical natural frequencies and should be avoided.

## 5.2.2 Acceptance criteria

Acceptance criteria shall be subject to agreement between the vendor and the purchaser prior to purchase installation. [Table 1](#) provides a basis for defining acceptance criteria for new or refurbished machines.

## 5.3 Guidance values for acceptable overall vibration values (2 Hz to 1 000 Hz)

### 5.3.1 Guidance value tables for displacement, velocity and acceleration

The guidance values for acceptable overall vibration displacement, vibration velocity, and vibration acceleration values for a horizontal and vertical compressor system are summarized in [Tables 2 to 4](#) and graphically shown in [Annex B](#).

Unless otherwise specified, the guidance values for V- and W-type compressors are the same as for vertical compressors. For L-type compressors, the values for the horizontal and vertical throw are the same as those for horizontal and vertical compressors, respectively.

The values for the piping can also be used as a first screening criterion for small bore piping. However, one should be careful in evaluating the vibration of small bore piping due to the fact that they are very sensitive to weld quality and bracing and supporting details.

**Table 2 — Summary of overall constant vibration displacement values for different compressor system parts**

Compressor system part	r.m.s vibration displacement values for horizontal compressors mm			r.m.s vibration displacement values for vertical compressors mm		
	Evaluation zone boundary			Evaluation zone boundary		
	A/B	B/C	C/D	A/B	B/C	C/D
Foundation	0,032	0,048	0,072	0,032	0,048	0,072
Frame (top)	0,084	0,127	0,191	0,084	0,127	0,191
Cylinder (lateral)	0,139	0,207	0,310	0,170	0,255	0,382
Cylinder (rod)	0,170	0,255	0,382	0,139	0,207	0,310
Dampers	0,202	0,302	0,454	0,202	0,302	0,454
Piping	0,202	0,302	0,454	0,202	0,302	0,454

**Table 3 — Summary of overall constant vibration velocity values for different compressor system parts**

Compressor system part	r.m.s vibration velocity values for horizontal compressors mm/s			r.m.s vibration velocity values for vertical compressors mm/s		
	Evaluation zone boundary			Evaluation zone boundary		
	A/B	B/C	C/D	A/B	B/C	C/D
Foundation	2,0	3,0	4,5	2,0	3,0	4,5
Frame (top)	5,3	8,0	12,0	5,3	8,0	12,0
Cylinder (lateral)	8,7	13,0	19,5	10,7	16,0	24,0
Cylinder (rod)	10,7	16,0	24,0	8,7	13,0	19,5
Dampers	12,7	19,0	28,5	12,7	19,0	28,5
Piping	12,7	19,0	28,5	12,7	19,0	28,5

NOTE For piping values above evaluation zone boundary C/D, see [Table 1](#), Note 3.

**Table 4 — Summary of overall constant vibration acceleration values for different compressor system parts**

Compressor system part	r.m.s vibration acceleration values for horizontal compressors m/s <sup>2</sup>			r.m.s vibration acceleration values for vertical compressors m/s <sup>2</sup>		
	Evaluation zone boundary			Evaluation zone boundary		
	A/B	B/C	C/D	A/B	B/C	C/D
Foundation	2,5	3,8	5,7	2,5	3,8	5,7
Frame (top)	6,7	10,1	15,1	6,7	10,1	15,1
Cylinder (lateral)	10,9	16,3	24,5	13,5	20,1	30,2
Cylinder (rod)	13,5	20,1	30,2	10,9	16,3	24,5
Dampers	16,0	23,9	35,8	16,0	23,9	35,8
Piping	16,0	23,9	35,8	16,0	23,9	35,8

### 5.3.2 Vibration values and the effect of mountings and foundations

The vibration values as given in [Tables 2 to 4](#) are valid for compressor systems mounted on rigid foundations. This means that the compressor and driver are mounted directly to the concrete foundation. If the compressor and driver are mounted on a skid, the skid shall be stiff enough and directly mounted to the concrete foundation. The structure on which the compressor is mounted, either concrete or skid, should not be in resonance. Operation at or near resonance should be avoided. Isolated mounted foundations, e.g. concrete block on springs and skids on anti-vibration mounts (AVM), are an exception and the acceptable vibration values for such systems should be agreed upon between the purchaser and the vendor.

### 5.3.3 Vibration values in the rod direction

The gas (stretching) force in the cylinder causes vibration in the rod direction. In general the vibration in the rod direction is larger than in the lateral direction. The vibration in the rod direction of the cylinder causes tensile and compression stresses and is generally considered less harmful than the lateral vibration which causes bending stresses. For that reason, larger vibration values in the rod direction of the cylinder are allowed than in the lateral direction.

### 5.3.4 Vibration values for vertical compressor systems

For vertical compressors, larger vibration values in lateral direction than in the rod direction of the cylinder are allowed due to the fact that the vertical compressor is in general more flexible in the lateral direction than a horizontal compressor.

## Annex A (normative)

### Measurement information requirements

#### A.1 Compressor details

Typically, for each compressor being measured, the following information should be recorded.

<b>Item</b>	<b>Example</b>
Unique compressor identifier:	equipment code or tag number
Compressor type:	gas compressor/other
Number of cylinders:	
Configuration:	horizontal/vertical/V-type/L-type/W-type
Rated rotational speed:	r/min or Hz
Constant or variable speed:	Constant or variable speed
Speed variation (if applicable):	minimum speed, maximum speed, r/min, or Hz
Rated power:	kW
Compressor support:	mounted on rigid foundation or resiliently mounted
Shaft coupling:	rigid or flexible
Type of flow control:	valve unloaders, bypass, clearance pocket, speed, stepless flow reversal control

It can also be useful to record the following information.

<b>Item</b>	<b>Example</b>
Driver type:	electric motor, internal combustion engine

## A.2 Measurements

For each measurement system, the following information should be recorded.

<b>Item</b>	<b>Example</b>
Date, time (including time zone) of measurement:	
Instrument type:	make and model of instrument
Measurement location:	drawing (preferred), description, or code
Measurement units:	mm/s; mm, $\mu\text{m}$ ; $\text{m/s}^2$
Measurement unit qualifier:	r.m.s
Measurement type:	overall/amplitude/spectrum/time history
Transducer type:	accelerometer, eddy current, velocity
Transducer attachment method:	probe/magnet/stud/adhesive
FFT or other processing:	filter (i.e. low and high cut-off frequencies), number of lines, number of averages, number of samples, window type
Calibration requirement:	type and date of last required calibration

The following process and operating parameters should also be recorded.

<b>Item</b>	<b>Example</b>
Speed during measurement:	r/min or Hz
Power during measurement:	kW
Operation of multiple compressors:	single, parallel
Load condition per compressor:	load %, load steps
Unloading method:	valve unloading (stepless or fixed), clearance volumes (fixed or variable)
Operating parameters:	pressures, temperatures, gas composition

## A.3 Other information

Extra information on the compressor and the measurements can be recorded in addition to the above, e.g. historical maintenance data. An example of a form to record asset and measurement data for the compressor types is shown in [Table A.1](#).

**Table A.1 — Form for recording typical compressor details**

<b>General</b>	
Record no.:	Installation site:
Date:	Measured by:
<b>Details of compressor system</b>	
Unique compressor ID no.:	Type/Serial no.:
Type: gas compressor/other <sup>a</sup>	Driver type: <sup>a</sup>
Number of cylinders: 1/2/3/4/5/6/8/12/other <sup>a</sup>	Coupling: rigid/flexible <sup>a</sup>
Configuration: horizontal/vertical/other <sup>a</sup>	Load condition during measurement:
Rated speed: r/min	Rated power: kW
Actual speed: r/min	Power during measurement: kW
Mounting: on rigid foundation/resilient <sup>a</sup> directly/on skid <sup>a</sup>	Running hours:
Vendor:	
<b>Details of each measuring system</b>	
Instrument make:	Instrument model:
Measurement units:	FFT or other processing details:
Measurement unit qualifier:	
Transducer type and make:	Attachment:
<b>Diagram</b>	Sketch compressor below:
Measurement records, readings, diagrams, etc. should be attached giving locations of measurement, and the conditions at the time of measurement, if applicable.	
<sup>a</sup> Delete/supplement as appropriate.	

## Annex B (normative)

### Curves with overall limits of vibration velocity values

#### B.1 Introduction

In this annex, the vibration values as given in [Tables 2 to 4](#) are presented in a graphical form as vibration velocities. The values were derived from constant vibration displacement in the frequency range 2 Hz to 10 Hz, constant vibration velocity from 10 Hz to 200 Hz, and constant vibration acceleration from 200 Hz to 1000 Hz. The frequencies of 10 Hz and 200 Hz are the corner frequencies.

NOTE For a deeper explanation of the velocity-based curves, see ISO 10816-1.

For sinusoidal signals, the relation between vibration displacement, vibration velocity, and vibration acceleration is as follows.

$$\text{Displacement: } x = \int v dt = \iint (a dt) dt = -\frac{i}{\omega} v = -\frac{1}{\omega^2} a \quad (\text{B.1})$$

$$\text{Velocity: } v = \frac{dx}{dt} = \int a dt = i\omega x = -\frac{i}{\omega} a \quad (\text{B.2})$$

$$\text{Acceleration: } a = \frac{dv}{dt} = \frac{d^2x}{dt^2} = -\omega^2 x = i\omega v \quad (\text{B.3})$$

where

$i$  is the imaginary unit;

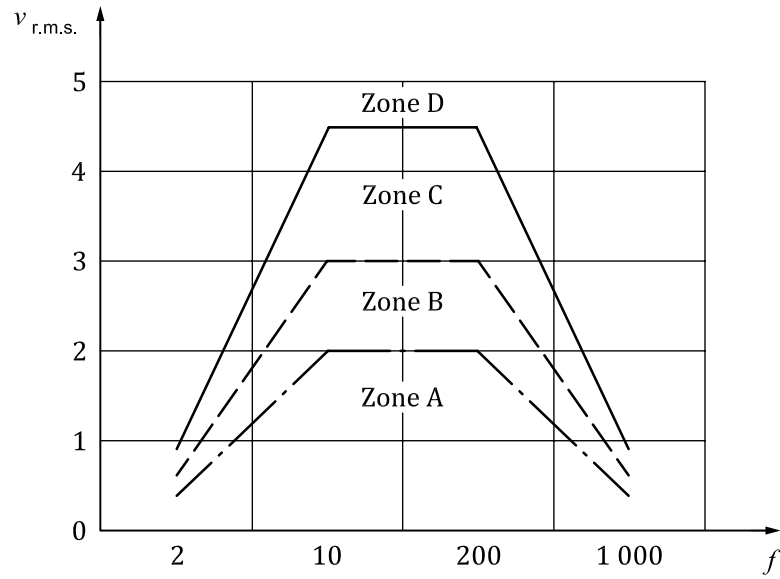
$\omega$  is the angular frequency of the vibration with  $\omega = 2\pi f$ .

These relations can, for example, be used to convert vibration displacement and vibration acceleration to vibration velocity at the 10 Hz and 200 Hz corner frequencies for a sinusoidal signal.

#### B.2 Curves with overall limits of vibration velocity values

Curves with overall limits of vibration velocity values for different parts of a compressor system are shown in [Figures B.1 to B.10](#).

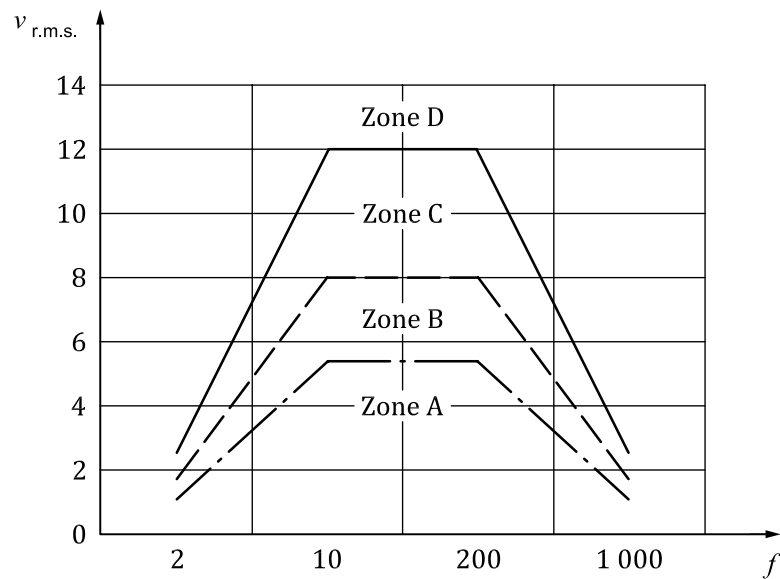




**Key**

$v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

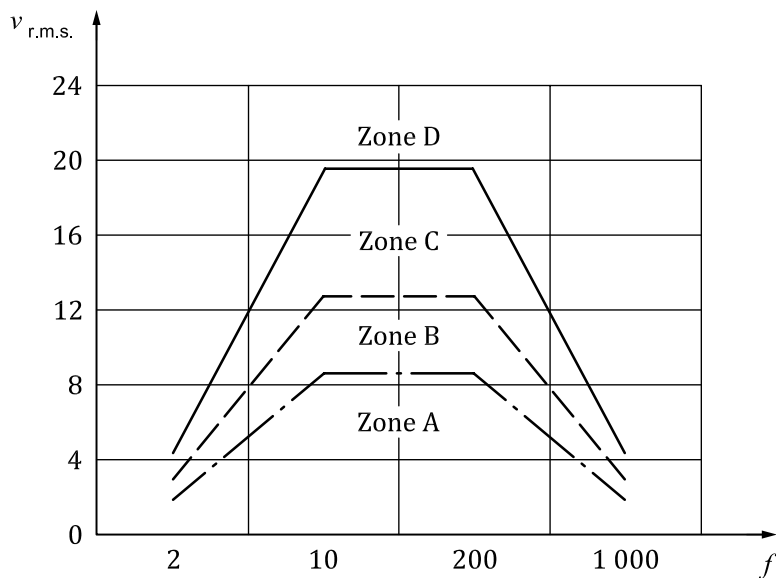
**Figure B.1 — Overall vibration velocity limiting curve for the foundation of a horizontal compressor**



**Key**

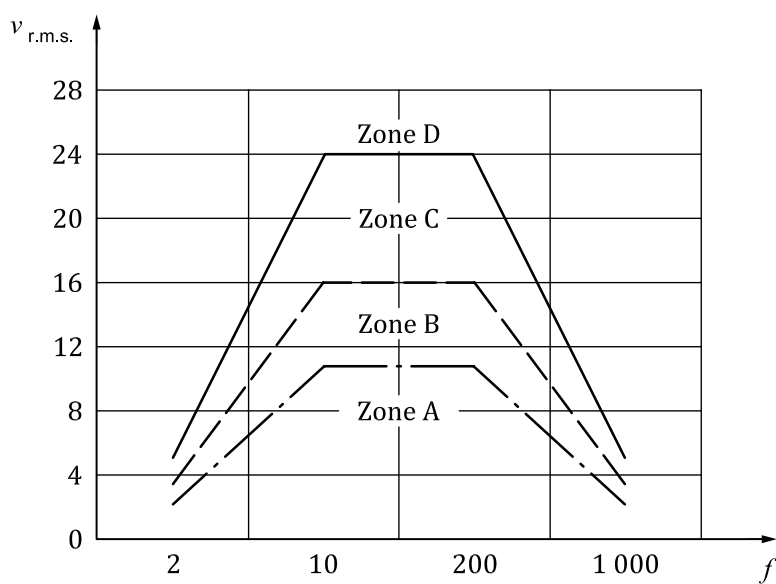
$v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.2 — Overall vibration velocity limiting curve for the frame of a horizontal compressor**



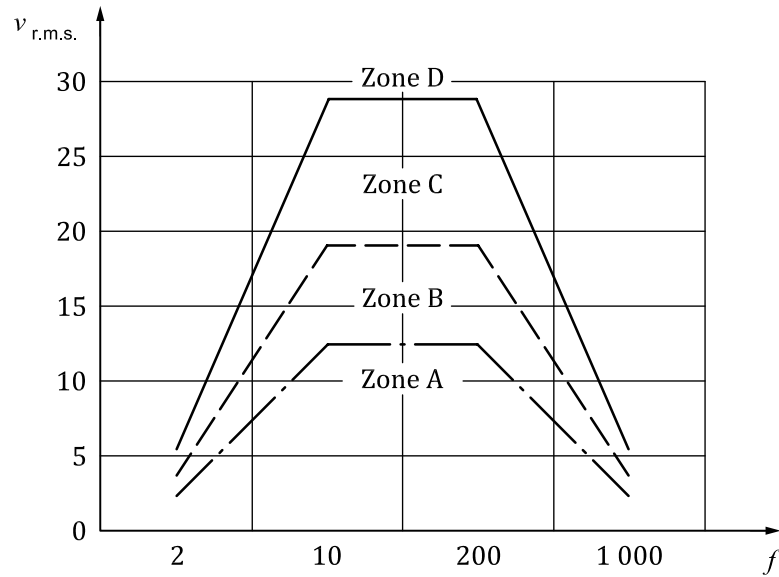
**Key**  
 $v_{r.m.s.}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.3 — Overall vibration velocity limiting curve for the cylinder in lateral direction of a horizontal compressor**



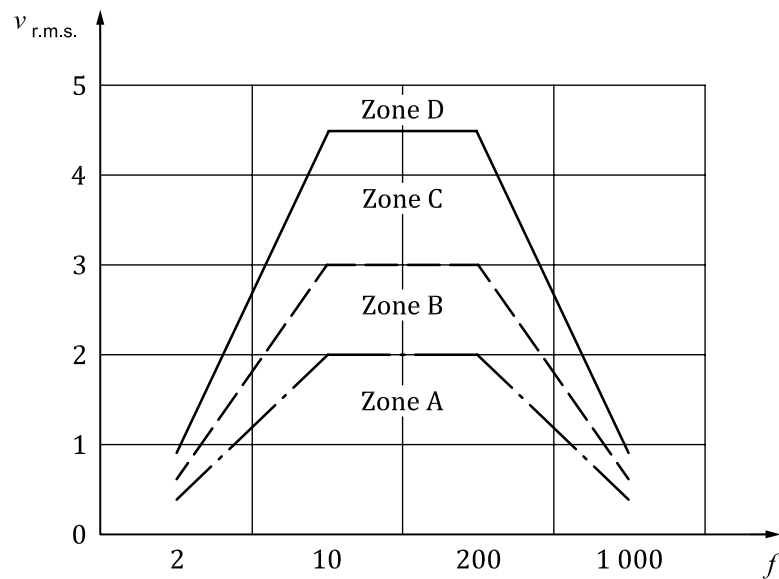
**Key**  
 $v_{r.m.s.}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.4 — Overall vibration velocity limiting curve for the cylinder in rod direction of a horizontal compressor**



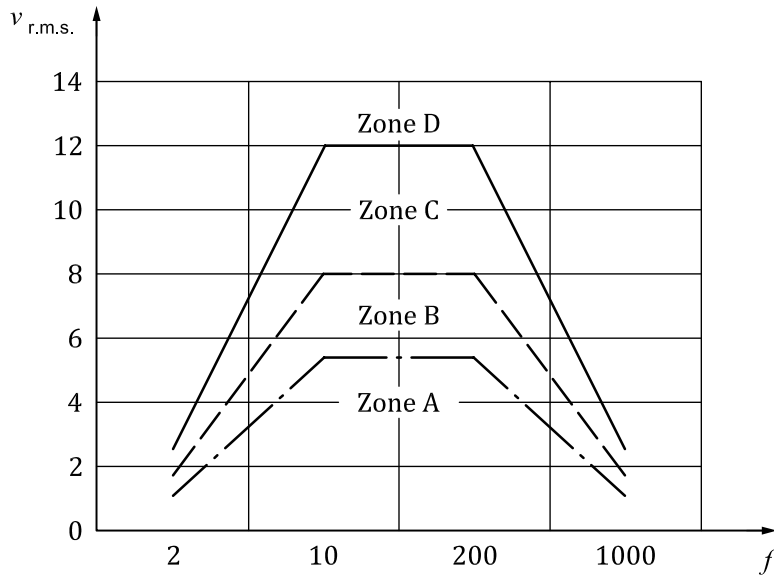
**Key**  
 $v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.5 — Overall vibration velocity limiting curve for the piping and dampers of a horizontal compressor**



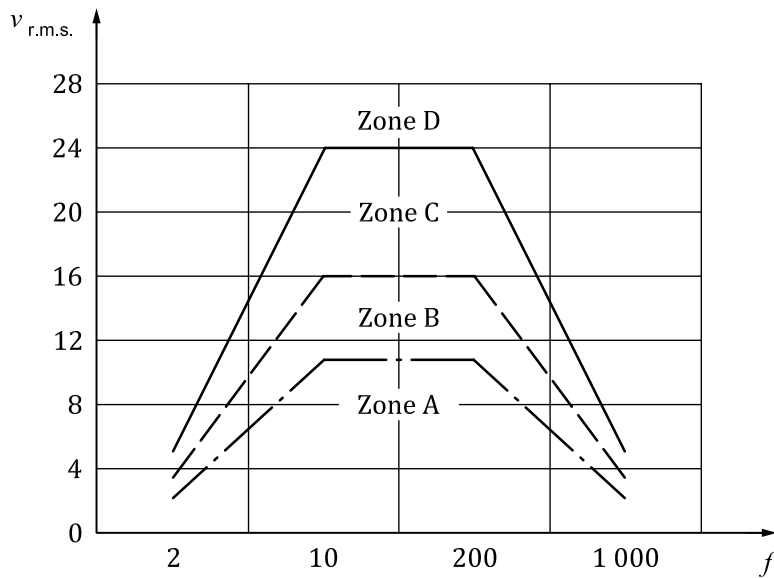
**Key**  
 $v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.6 — Overall vibration velocity limiting curve for the foundation of a vertical compressor**



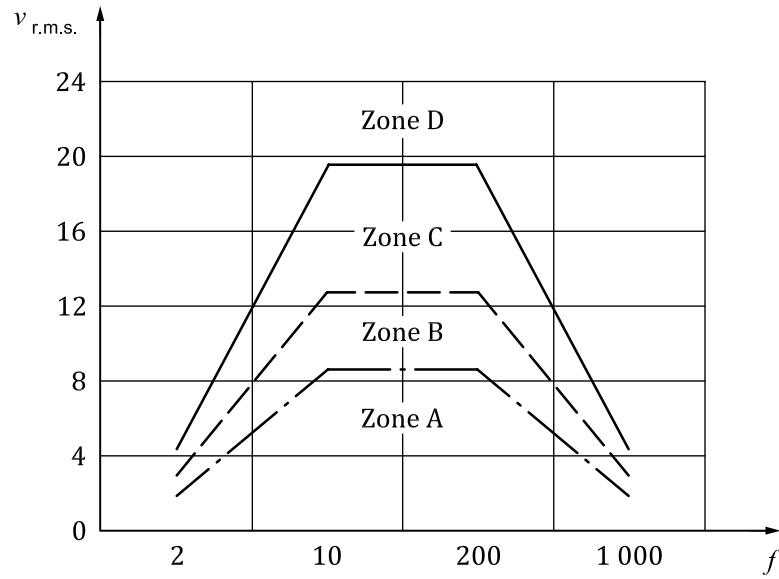
**Key**  
 $v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.7 — Overall vibration velocity limiting curve for the frame of a vertical compressor**



**Key**  
 $v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

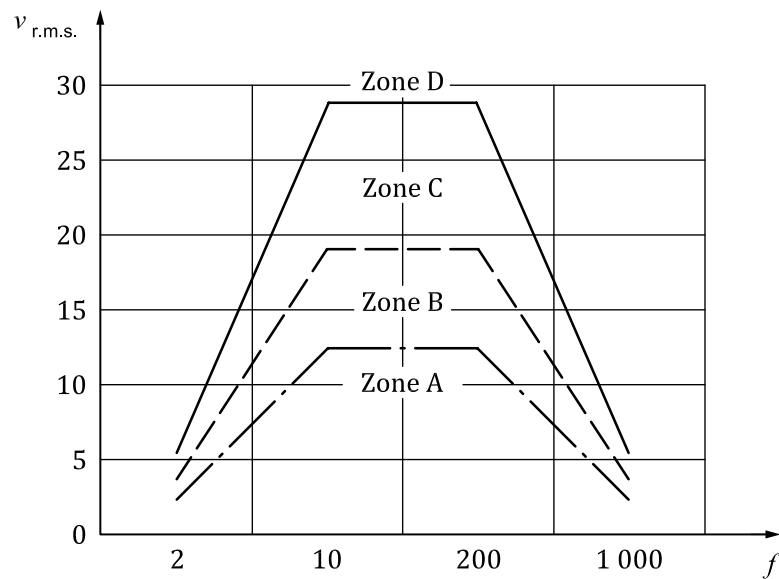
**Figure B.8 — Overall vibration velocity limiting curve for the cylinder in lateral direction of a vertical compressor**



**Key**

$v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.9 — Overall vibration velocity limiting curve for the cylinder in rod direction of a vertical compressor**



**Key**

$v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure B.10 — Overall vibration velocity limiting curve for the piping and dampers of a vertical compressor**

## Annex C (informative)

### Measurement of vibration values on the crosshead guide

#### C.1 General

Accelerometers are often mounted on the crosshead guide for condition monitoring purposes of internal compressor components. The vibration is measured in the direction of the force exerted by the crosshead on this guide, which is in the vertical direction of a horizontal compressor. Experience on horizontal compressors has shown that the vibration values measured on the crossheads guide can be used in addition to the vibration values of other locations to judge the integrity of the compressor. The procedures for measuring the vibration values on the crosshead guide are outlined in this annex and are limited only to horizontal compressors.

Crosshead guide impact measurements (typically as vibration acceleration) are subject to mounting, compressor loading, speed, rotational direction, transducer type, structure resonance, and sampling techniques. Therefore, it is often used as a trending tool with ALARM and TRIP (shutdown) limits determined from normal running conditions. The limits provided below are interpolated from the standard guidelines from 2 Hz to 1 000 Hz and can be used for guidance, but can be subject to change depending on the actual conditions and design of the machine.

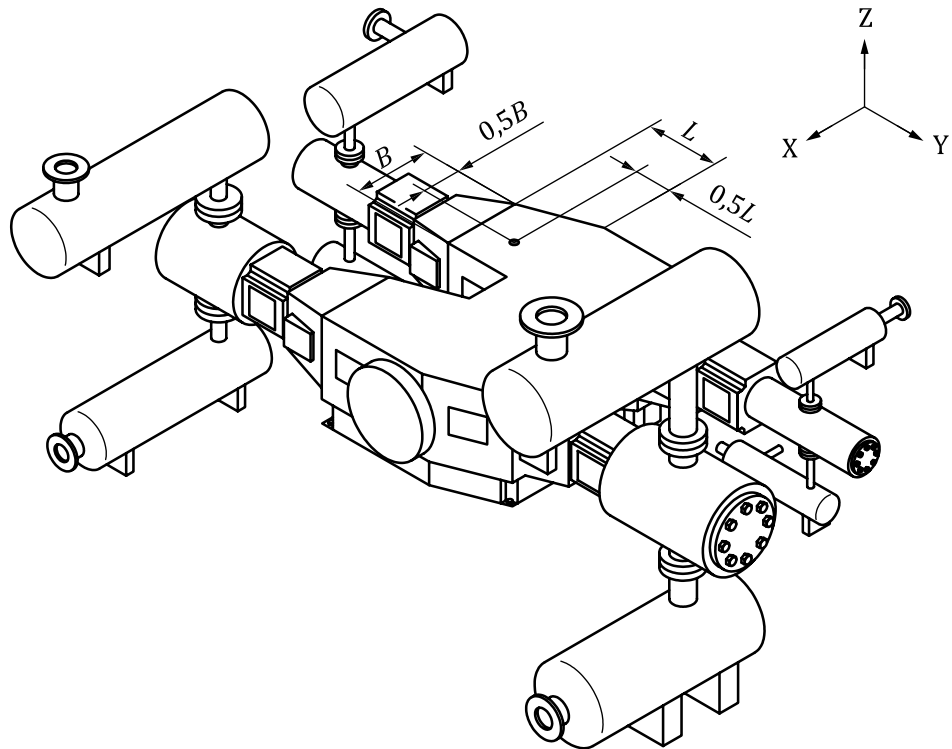
#### C.2 Locations and direction of measurements

##### C.2.1 Location

For horizontal compressors, the measurements on each crosshead guide should be taken on the marked location indicated by the compressor OEM. If there is no marked location, on top in the centreline of the throw halfway along the length of the crosshead guide, see [Figure C.1](#). This location needs to be a stiff structural part which might need verification on the OEM machine drawings.

##### C.2.2 Direction of measurements

The measurements should be taken in the direction of the force exerted by the crosshead on this guide, which is the vertical direction of a horizontal compressor.



**Key**

- $L$  length of crosshead guide
- $B$  width of crosshead guide

NOTE The measurements should be carried out on the crosshead guide of each throw.

**Figure C.1 — Crosshead guide locations on a horizontal compressor**

### C.3 Guidance values for acceptable overall vibrations for the crosshead guide

Overall vibration values for the crosshead guide in terms of displacement, velocity, and acceleration are given in [Tables C.1](#) to [C.3](#).

**Table C.1 — Summary of overall vibration displacement values of the crosshead guide**

Compressor system part	r.m.s vibration displacement values for horizontal compressors mm		
	Evaluation zone boundary		
	A/B	B/C	C/D
Crosshead guide	0,095	0,143	0,215
NOTE Displacement limits are generally not used on crosshead guides.			

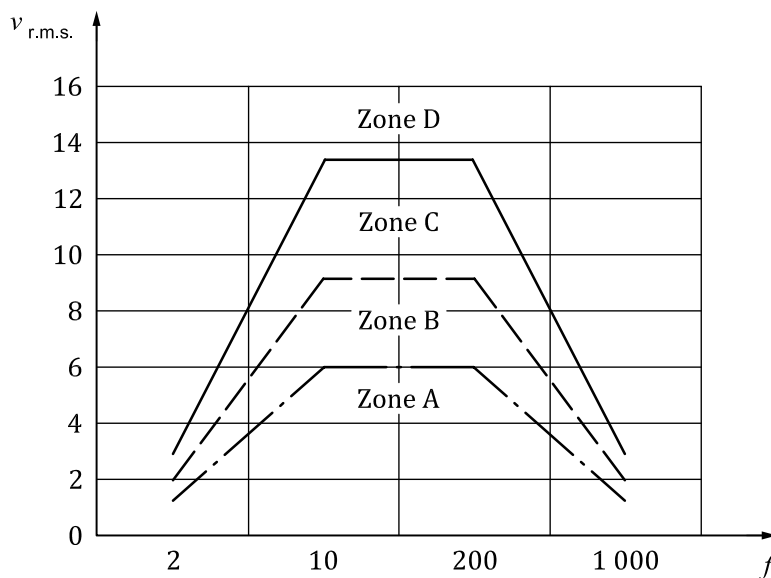
**Table C.2 — Summary of overall vibration velocity values of the crosshead guide**

Compressor system part	r.m.s vibration velocity values for horizontal compressors mm/s		
	Evaluation zone boundary		
	A/B	B/C	C/D
Crosshead guide	6,0	9,0	13,5

**Table C.3 — Summary of overall vibration acceleration values of the crosshead guide**

Compressor system part	r.m.s vibration acceleration values for horizontal compressors m/s <sup>2</sup>		
	Evaluation zone boundary		
	A/B	B/C	C/D
Crosshead guide	7,5	11,3	20,0
NOTE Acceleration limits are generally preferred on crosshead guides.			

The corresponding curve with limits of overall vibration velocity for the crosshead guide of a horizontal compressor is shown in [Figure C.2](#).



**Key**  
 $v_{r.m.s}$  r.m.s vibration velocity, in mm/s  
 $f$  frequency, in Hz

**Figure C.2 — Overall vibration velocity limiting curve for the crosshead guide of a horizontal compressor**



## Annex D (informative)

### Root-mean-square value, peak value, and crest factor

#### D.1 Introduction

The root-mean-square (r.m.s) value as used in this part of ISO 10816 tends to be a much more consistent measure as sinusoidal data dominate the energy content in this type of calculation.

A disadvantage of the r.m.s value is that short duration spikes in the vibration signal (especially in the accelerations), which can be audible in nature (knocking), do not have much energy and, therefore, are not necessarily represented in an r.m.s measurement. Large-amplitude acceleration spikes also have small vibration displacement and vibration velocity values due to the integration of the measured vibration acceleration signals.

Spikes in a vibration signal can indicate, for example possible large local stresses in a part of the compressor system, or can indicate looseness of internal or external components. The peak value of a vibration signal is, for that reason, a better measure to detect looseness and to represent the stress due to the fact that the peak value is proportional to the cyclic stress in the material.

There is not a simple mathematical relation between r.m.s and peak value; however, crest factors can be a useful way to convert an r.m.s vibration value into a peak value. The r.m.s vibration value from this part of ISO 10816 can be converted to a peak vibration value if the crest factor is measured.

In this annex, root-mean-square, peak, and crest factor values are explained and can be used to indicate the relationship of r.m.s vibration value to peak vibration value.

#### D.2 Root-mean-square value, peak value, and crest factor

##### D.2.1 Root-mean-square value

The root-mean-square or r.m.s value  $U_{\text{r.m.s}}$  of a vibration signal is given by

$$U_{\text{r.m.s}} = \sqrt{\frac{1}{T} \int_0^T u^2(t) dt} \quad (\text{D.1})$$

where

$u(t)$  is the time-dependent vibration signal;

$T$  is the averaging time.

NOTE The r.m.s value defined by Formula (D.1) is also named true r.m.s value.

##### D.2.2 Peak value

The peak value  $\hat{U}$  of a vibration signal  $u(t)$  is the maximum value during a specified time interval.

NOTE 1 The peak value of a vibration is usually taken as the maximum deviation of the vibration from its mean value. A positive peak value is the maximum positive deviation and a negative peak value is the maximum negative deviation.

NOTE 2 One has to be aware that other conventions for peak values are used which are not in accordance with International Standards, such as the following:

- True Peak (tP) [also named peak (p) or zero-to-peak (0-p)] is defined as the difference between the maximum and minimum value of a vibration signal during a specified time interval divided by 2 and, in this respect, the True Peak definition differs from the peak value definition in ISO 2041.
- Pseudo Peak (pP) [also named calculated peak (cP) or derived Peak (dP)]:  $pP = \sqrt{2} U_{r.m.s}$ . Pseudo Peak is based on the conversion between peak and r.m.s for a single sine wave. While Pseudo Peak has no direct mathematical relationship with a complex waveform, it is often used as a quick reference between r.m.s and peak. Such relationship can be useful but one has to be aware that a Pseudo Peak value can be smaller (e.g. triangle, saw tooth), equal (pure sine), or larger (e.g. square, block) than a True Peak value.

### D.2.3 Crest factor

The crest factor  $C_F$  of a vibration signal is the ratio of the peak value  $\hat{U}$  to the r.m.s value  $U_{r.m.s}$ :

$$C_F = \frac{\hat{U}}{U_{r.m.s}} \quad (D.2)$$

NOTE 1 One has to be aware that several other definitions of crest factor can be used, e.g. more than one (true) peak value is commonly applied.

NOTE 2 Crest factors based on true peak values typically range from 2 to 4 based on measurements for reciprocating compressor systems if minimal impacting is occurring. They can be several times larger if objects are responding to strong impact forces. Other types of positive displacement compressors or pumps can have larger crest factors.

NOTE 3 Objects that are dominated by a pure tone resonance (e.g. small bore attachments) near a sinusoid crest factor of  $\sqrt{2}$ .

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